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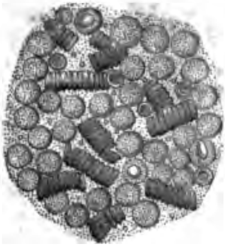

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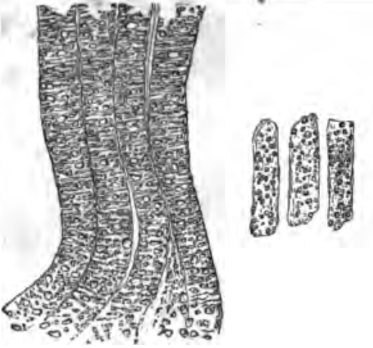

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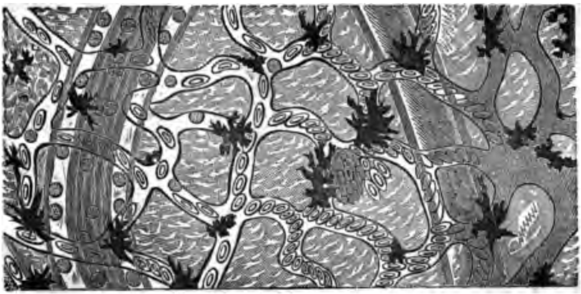
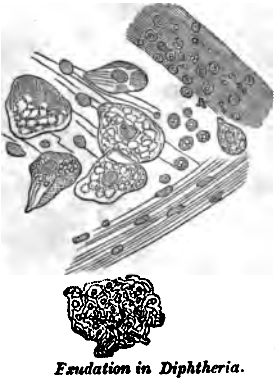
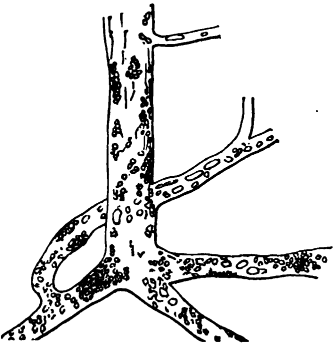


Frog's Webb.—Health. *Congestion.* *Inflammation.*



Exudation in Diphtheria.



Artery in Softened Brain.

Wm. Oldham, Sc. *After Bennett, Paget, & Beale.*

DISEASED STATES OF BLOOD AND BLOOD-VESSELS.

MANUAL OF PHYSIOLOGY

AND OF

THE PRINCIPLES OF DISEASE.

BY

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TO THE LATE

JOHN HATCH POWER, M.D.,

PROFESSOR OF SURGERY, ROYAL COLLEGE OF SURGEONS IN
IRELAND,

The first edition of this Book was Dedicated;

AND

IN REVERENCE FOR HIS MEMORY, THIS PAGE IS STILL

INSCRIBED WITH THAT HONORED NAME.

PREFACE.

DURING the two sessions which have elapsed since the publication of this Manual, the sciences of Physiology and Pathology have made considerable progress, and the principal results will be found embodied in this edition; also advantage has been taken of suggestions by judicious critics, and by many teachers who have recommended it as a text-book to their classes. While my further experience has, I trust, enabled me to arrange the matter in a more intelligible and practical way, my object still has been "to express the leading facts of the science in as few words as possible, leaving them to be amplified, or freed from any obscurity, by the reflection of the reader or the expository powers of the lecturer."

The unusual course of appending questions upon the more essential points of each section, has been adopted with the hope that it may aid in diffusing a knowledge of that science, which of all others is best calculated to exalt the healing art.

In the second part of this manual, the alterations in physiological processes, which are wrought by disease and the influence of remedies upon them, are explained, though very briefly; and in another work I have striven to apply the principles of Physiology to the subject of the maintenance of the health and life of communities.

E. D. MAPOTHER.

125 *Stephen's Green,*
1*st October*, 1864.

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*** *All quantities, save when otherwise stated, are calculated to the proportion of* 1000.

*** *All measurements, save when otherwise stated, are in vulgar fractions of an English inch.*

A MANUAL OF PHYSIOLOGY,

AND OF

THE PRINCIPLES OF DISEASE.

INTRODUCTION.

Physiology studies the phenomena of organised beings, and is therefore a great department of natural science. It is divided into vegetal and animal; and the latter is subdivided into comparative and human, which last branch of the science is the subject of the present volume, the structure or functions of the lower animals being referred to but incidentally.

There is no branch of knowledge whose limits are more hard to define, nor is there any which requires a more extensive acquaintance with preliminary and collateral sciences, such as Anatomy, Physics, and Chemistry; while, on the other hand, so imperceptible is the distinction between most of the normal and abnormal processes, that the physiologist is often compelled to enter the special domain of Pathology. This circumstance is the less to be regretted, as no study can be more fitted to introduce the student of Medicine to a scientific comprehension of the principles of disease, or to free its treatment from empiricism.

All important advances in Pathology have had their rise in accurate observation of, and rational deductions from, physiological phenomena; and disease can be shown to be, in every instance, but an increase, decrease, or perversion of normal function.

Foremost among the sciences which aid the study of Physiology is that of General Anatomy, which for this reason is aptly termed Physiological Anatomy, and is, for convenience sake, usually removed from the study of Descriptive or Surgical Anatomy; in this work it is treated of before the function of each organ is discussed, a short account of its Descriptive Anatomy being however prefixed, when necessary for the comprehension of its actions. To the improvements of the microscope, and the ardour with which it is employed, may be attributed the rapid advance which this branch of Physiology, often termed Histology, has made of late years.

The Vital Phenomena which the human body manifests admit of ready classification into those which it exercises in common with all other organic beings, and those which are peculiar to animals. Such was the view of *Bichat* when he spoke of the functions of "organic," or vegetative, and of "animal" life. Under the former head may be ranged the processes of digestion, absorption, circulation, respiration, and secretion, which may be grouped together as being subservient to the great function of nutrition; under the latter may be considered the higher endowments of sensation and voluntary motion.

Both organic and animal functions above enumerated relate to the individual alone; but that of reproduction, common both to the vegetal and animal world, has, as its aim, the maintenance of the species.

These views have been borne in mind in arranging the following pages.

We shall here consider the structural elements of which the human body is built up, reserving a more special account of the histology of each organ or tissue until we are describing the functions to which they minister.

In 1838, *Schwann* and *Schleiden* demonstrated that the nucleated cell in both animals and plants was the essential structural element in all the tissues, and the active agent in all the organic processes.

A Cell consists of a homogeneous cell-wall and contents, which usually include a nucleus or nuclei, and within these often nucleoli. As the nucleus is regarded as the formative part, the term cytoblast is often applied to it, the matter in which cells are formed, cytoblastema, and the process, cytogenesis. The typical shape is the sphere, but by mutual pressure they usually assume a polyhedral form. A few of the more remarkable shapes which will be illustrated in the ensuing pages may be here mentioned: spheroid cells compose glandular epithelium; regular hexagons the membrana pigmenti; the blood cells are biconcave discs; nerve cells are caudate; muscle cells are fusiform, and the cells of epidermis and tesselated epithelium gradually flatten into scales as they approach the surface.

The Phenomena of Cell-life are various. 1. Growth, by the appropriation of the special material of each kind of cell. 2. Multiplication, either by fission, as can be noticed in the blood cells of the chick, or endogenous transformation of its nuclei, as occurs in cartilage. 3. Change of form, special to each tissue. 4. Chemical changes of the contents; and 5. The generation of nerve force, which is the most wonderful of all its powers.

These remarkable objects can be artificially generated, for it will be found that perfect cell-walls are produced when an intimate admixture of oily and albuminous matters is made.

The Cell theory supposes that all organic bodies, no matter how complex their construction, as likewise all their tissues, modified though they may be, have originated from a cell or cells. Of the tissues which are thus temporarily cellular may be mentioned, fibrous tissue, muscle fibrils, nerve tubes, blood-vessels; and of those that remain permanently so, the following are examples—lymph and blood cells, nerve cells, fat cells, pigment cells, gland cells, cartilage cells; and, amidst the products of disease, pus cells, cancer cells, and many others. Thus, both in Physiology and Pathology does the aphorism seem applicable, "Omnis cellula e cellulâ."

There are some, however, who advocate the "molecular theory," which supposes that cell formation is preceded by molecules, or minute granules, which therefore should be considered the histological starting point. Thus *Prof. Bennett* believes that the molecules of chyle and the intimate constituents of muscle must be regarded as antecedent to the existence of any cell.

There are, again, some matters in the human body which, from the non-discovery of any structure, are called amorphous or hyaline; for example, the cell-wall, basement membrane, myolemma, neurilemma, the intercellular substance of cartilage, the elastic laminæ of the cornea, capsule of the crystalline lens, &c.

The illustrious *Baron Haller* regarded fibrous tissue as the simplest constituent of the human body, remarking that the fibre was to the physiologist what the line was to the geometrician; and many later histologists have adopted his view.

The general properties of the tissues may be here briefly discussed; and they readily arrange themselves as, 1. Physical; and 2. Vital.

1. **Divisibility** has always excited the wonder of those philosophers who study the phenomena of inorganic bodies, and the minuteness of many living organisms is no less astonishing. Thus, there are about eleven millions of exquisitely regular cells in the choroid pigmentary membrane, sixty-five and a-half millions of fat cells in the space of a cubic inch of adipose tissue, and one hundred and fifty millions of moving cilia throughout the air tubes of man. Activity is always proportional to minuteness of division.

Extensibility is a universal property of animal tissues; but its amount varies most widely, being, like the cognate property of pliancy, dependent on the amount of water each contains. The order of those of the dead body is as follows—muscle, vessels, nerve, hair, tendon, and bone.

Elasticity, by which the tissues re-act when a compressing or extending force is removed, is another striking physical endowment, especially conferred on the yellow fibrous tissue. Between the atoms which constitute living as well as inanimate bodies spaces must be conceived to exist, more or less considerable as the state of aggregation be the gaseous, liquid, or solid forms. To this porosity is due the osmose and dialysis, or interchange of liquids and gases which, as the following pages will show, constitutes the very fundamental nature of most physiological processes. In the human body there are likewise constantly taking place chemical changes, which will be presently referred to, and which are essential to the continuance of life. They are moreover so diverse, that the truths about them have been justly remarked to be more wonderful than the fabled transmigration of souls.

2. **The Vital Properties** of animal tissues are evidenced by molecular changes which follow the application of a stimulus. Such are contractility, the endowment of muscle, and neurility, which term conveniently groups the phenomena of common sensation, special sensation, and motive influence, with which both vesicular and tubular neurine are concerned, and the higher intellectual endowments of the nervous centres.

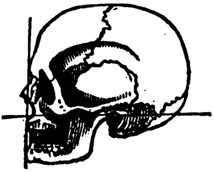
Between the physical forces, as *Grove* has demonstrated, and likewise between the vital, there exists mutual dependence or correlation ; and it is the intimate union or sum of their phenomena we designate as "Life."

Before discussing the several functions, and the structural anatomy of the organs by which they are performed, I have deemed it advisable to notice briefly the characters which place man at the head of the organic world, and to consider the chemical features of the substances which constitute his body.

NATURAL HISTORY OF MAN.

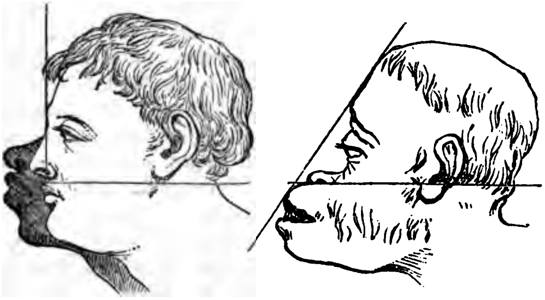
Man, zoologically considered, belongs to the class Vertebrata; order, Mammalia; sub-order, Hominidæ; genus, Homo; and species, Sapiens; according to *Linnæus*, who gave as his characteristic the aphorism, "Nosce te ipsum." In the words of *Owen*, "man is the sole species of his genus (Homo)—the sole representative of his order (Bimana);" and it is equally unscientific and irreverent to group him, as *Linnæus* and some other naturalists have done, with Quadrumana, in the order Primates. His distinctive characters are thus enumerated by *Blumenbach*:—"Erect, two-handed, unarmed, rational, endowed with speech, a prominent chin, four incisor teeth, above and below; all the teeth equally approximated, the canine teeth of the same length as the others, the lower incisors erect."

The erect posture, an attitude peculiar to the human species, is preserved by the occipital condyles being placed on the base of the skull, as near the centre as can be allowed without the heavy, bony cranium and brain overbalancing the light, spongy bones of the face. The equilibrium is, however, maintained in some degree by muscular power; for if this is suspended, as when we nod in sleep, the head falls forward. The cranium then rests easily on the vertebral column, and all the great occipital and vertebral ridges are absent; the ligamentum nuchæ is hardly developed. The face is placed rather below the cranium than in front of it, as in brutes—even the most anthropoid. This circumstance is best determined by what *Camper* termed "the facial angle," formed by drawing one line from auditory meatus to root of nose, and another touching the forehead and upper jaw, as here represented. The



Camper's Facial Angle, 85°.

angle so included increases through mammalian skulls till it becomes 35° in the Troglodytes Gorilla, the most anthropoid of apes, according to *Owen*, who has shown that the much greater angle assigned to this animal by other writers depends on their having examined the skull before second dentition, after which period the jaws become more prognathous, or snouty, and the angle much less. Even in the adult gorilla's skull, the angle is not an index of cerebral proportions, as it is greatly exaggerated by a prominent supra-orbital ridge. From 70° in the Negro it increases to 80° or 85° in the European, and to 90° or 100° in the statues of Apollo and Medusa of Sisocles, which the Grecian artists thus endowed with sublimity and beauty. The difference between the quadrumana and man is vastly greater than between any human varieties. The angle as found in the Ethiopian and Caucasian races, and in the Chimpanzee, is here represented. *Prof. Owen* draws the lower line from occipital condyles along floor of nose, and thus includes a greater angle. The orbits are directed forwards, and the eyes are parallel. Man's spine, admirably curved to adapt his body to the erect posture, differs from that of quadrumana in the cervical spines being bifid, and in having one more lumbar ver-



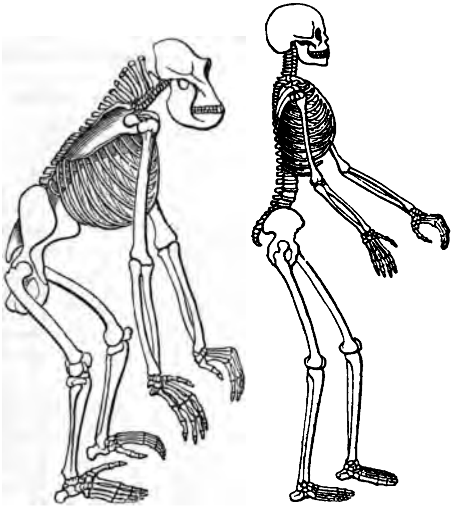
Prognathous face of Negro; Grecian head, 95°; and Gorilla, 40°.

tebra. The sacrum and coccyx are inclined forward, as also are the genito-urinary passages. The pelvic bones are laterally expanded, and the more so, *Vrolik* has shown, as we ascend the scale of human beings, bearing the weight of the viscera above them. The femur (especially at its neck) is longer, as well as the whole lower extremity, so that while the hands reach to the ancles in the ourang, they but touch the middle of man's thigh. The femoro-tibial surfaces are very broad, and the foot most remarkable for size, curved form, projection of calcis, which, with the big toe, are supporting surfaces so perfect, that man alone can stand on one limb. The kangaroo alone is said to excel man in length of leg and size of foot. The inner toe or hallux of apes is small, posterior not supporting, but opposable, like a thumb; hence their specific designation of "four-handed." Other evidences of the erect attitude are seen in the superior size of the muscles of the buttock, and of the calf, and in the great flexor pollicis being inserted into the big toe alone, and not three middle toes as in quadrumana. The tales then of men adopting the prone position in *Lord Monboddo's* works, and the account of "Peter, the Wild Boy," quoted by *Blumenbach*, may be now regarded as ludicrous misconceptions.

Another most admirable human attribute is the hand, which the beautiful discourse of Sir *C. Bell* has shown does not really exist in lower animals, in whom nothing comparable to the "extensor indicis," to the thumb, firmly opposable by its great muscular ball to all the fingers, nor to the exquisite mobility or tactile sense of the fingers, can be pointed out. Of this wonderful instrument, which has been the means of spreading intellectual culture over the globe, *Quintilian* said :—'Nam ceteræ partes loquentem adjuvant, hæ prope est ut dicam, ipsæ loquuntur. His poscimus, pollicemur, vocamus, dimittimus minamur, supplicamus, timemus; gaudium tristitiam, dubitationem, confessionem, penitentiam modum, copiam, numerum, tempus ostendimus." Other characteristics are, smoothness of skin, scantiness of hair, and preponderance of it on the ventral aspect, and the absence of weapons of defence. Reason has, however, enabled him to construct the deadliest engines, and to subjugate other creatures as ministers of his wants and pleasures.

Man's teeth are equal in length, so that the canine attains no greater size than others, and those of the upper and lower jaw form corresponding lines, without any break or diastema, which occurs in all animals save the fossil genus anoplotherium. The premaxillary bone, which is large in most animals, and contains the incisor teeth, is scarcely present save in the earliest embryonic period. It existence was, however, demonstrated by the immortal poet and anatomist *Goëthe*. Surgeons have to deal with it in the malformation termed "double hare lip."

Prof. Owen justly considers the gorilla to be the most anthropoid of all quadrumana; yet, in the skull alone he enumerates thirty differences from that of man. There is, for instance, the great size of the canines, which are, moreover, intended for combat, not for prehension of food, as the animal is frugivorous. Again, these canines are larger in the male, being divided by a diastema from the incisors in the upper jaw, and from the premolars in the lower. Then the two rows of molars are parallel, the premaxillary bone, lower jaw, and zygoma large and well developed, and the face prognathous. The cubical capacity of the smallest human skull equals 63 cubic inches, whereas the largest gorilla cranium measures but 34·5. The distinctive characters of man's brain, and that of anthropoid apes, have given rise to one of the most famous of scientific controversies; *Prof. Owen* asserting that in man alone does the posterior lobe overlap the cerebellum, and in him alone is found the posterior cornu of the lateral ventricle and its hippocampus minor—statements energetically denied by *Prof. Huxley* and other anatomists. The greater weight of the trunk, the length of the arm, the slight curves of the vertebral column, the inconsiderable lateral expansion of the pelvic bones, the latissimus dorsi being inserted into the olecranon, and being thirteen pairs of ribs, may be noted as also remarkable.



Comparative view of Skeletons of Gorilla and Man, after Huxley.

Having now mentioned the most striking differences in the anatomical conformation of man and those creatures below him, it may be allowed that there are few peculiarities in his physiological functions, except his wonderful adaptibility to the most diverse conditions of climate, food, and other physical circumstances, which that order of beings approaching him nearest is, strange to say, least of all able to endure. Man's growth is slower, maturity not being attained till beyond the age of twenty ; but his longevity is greater, as shown by the following

LIFE TABLE FOR ENGLAND.

Age.	Living.	Males.	Females.	Expectation of Life.	
				Males.	Females.
—	100,000	51,274	48,726	40·19	42·18
1	85,369	43,104	42,265	46·71	47·55
2	80,102	40,388	39,714	48·82	49·57
3	77,392	39,018	38,374	49·52	50·29
4	75,539	38,064	37,475	49·74	50·48
5	74,201	37,385	36,816	49·64	50·38
10	70,612	35,564	35,048	47·08	47·81
15	68,627	34,573	34,054	43·35	44·13
20	66,059	33,324	32,735	39·88	40·81
25	63,295	31,958	31,337	36·47	37·52
30	60,332	30,473	29,859	33·13	34·25
35	57,172	28,867	28,305	29·83	30·99
40	53,825	27,145	26,680	26·56	27·72
45	50,301	25,311	24,990	23·30	24·43
50	46,621	23,376	23,245	20·02	21·07
55	42,796	21,355	21,441	16·68	17·63
60	37,996	18,808	19,188	13·59	14·40
65	31,852	15,589	16,263	10·86	11·52
70	24,531	11,823	12,708	8·51	9·03
75	16,664	7,867	8,797	6·53	6·92
80	9,398	4,316	5,082	4·92	5·20
85	4,021	1,780	2,241	3·64	3·83
90	1,140	481	659	2·68	2·77
95	174	69	105	2·22	2·06
100	16	7	9	—	—
104	2	1	1	—	—

It shows the number of males and females (the equality of whom affords a strong argument for monogamy) who will be found living at each period of years, and the probable duration of their life if 100,000 infants be taken. The weight of the human body varies less than that of other animals, as determined by *Quetelet's* famous calculations, which, being useful as standards, are here given in pounds avoirdupois :—

	Maximum.	Minimum.	Mean.
Male	218	108	140
Female	206	140	121

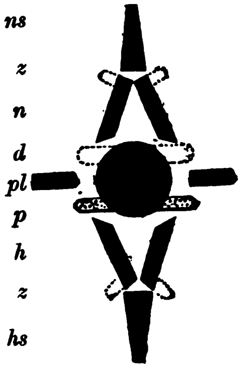
Still further, man differs from other animals in the powers of his mind, in the variety, force, and delicacy of his feelings, in the vast prerogative of articulate speech, and, above all, in the possession of an immortal soul. The belief in a Supreme Being, and in a future state, is in all men innate, or natural, and easily developed. He alone endeavours to mitigate the sufferings of his fellow-beings—a consideration which much enhances the dignity of Medicine. Susceptibility of education he shares, to a certain limited extent, with the lower animals ; but to him alone is given the privilege of progress from age to age, so that each generation inherits the experience and acquisitions of its predecessors, and humanity grows wiser and wiser as it advances.

> " 'Tis the sublime of man,
> Our noontide majesty, to know ourselves—
> Part and proportion of a wondrous whole."

So strongly marked are the distinctions, both structural and psychological, between man and all beings below him, that they afford (especially as no efficient modifying circumstances have been suggested) weighty arguments against the doctrine of " progressive development," for, as *Owen* remarks, "Nine-tenths of the differences which have been cited as distinguishing the great chimpanzee from the human species, must stand in contravention of the hypothesis of transmutation and progressive development, until the acceptors of that hypothesis are enabled to adduce the facts demonstrative of the condition of the modifiability of such characters."

That there is, however, unity of type pervading the whole animal kingdom, comparative anatomy has long taught, and that this unity exists in the parts of the same animal has, of late years, been demonstrated. The importance of the vertebræ as segments of the neuroskeleton of the higher animals had been long known, when, in 1806, it occurred to *Oken* that the bones of the skull, however complicated, were yet but modified vertebræ. Another homology was soon discovered by *Spix*, who regarded the maxillary arch, "the arm of the head," a view which their being both used in prehension of food strengthens. Such doctrines were scoffed at as "transcendental;" and, even in 1845, the editor of *Cuvier's* works, exclaims: "Pour moi une mâchoire supérieure est une mâchoire supérieure et un bras est un bras. Il ne faut pas chercher à faire sortir, l'osteologie d'un systéme de metaphysique." To which *Owen* replies: "But a jaw is not the less a jaw because it is a hæmapophysis, nor is an arm the less an arm because it is a diverging appendage." In the same spirit a critic might write: "Newton called this earth a planet, and the moon a satellite. For me, the earth is an earth, and the moon is a moon. One must not strive to make an ouranology out of a system of metaphysics." The vertebræ are similar bony segments, jointed in a horizontal line in lower animals, and piled vertically in the skeleton of man. Each is composed of a number of parts, developed in some instances, suppressed in others, but all represented in what is termed the "typical vertebra," and exhibited in the following figure, with the name opposite to each. The parts enclose a space above termed the "Neural arch," as it lodges the great nervous centre, and another below, which, protecting the great blood-vessels and nutritive organs, is called the "Hæmal" or "Visceral arch." It must be borne in mind that this typical vertebræ is ideal; yet it may be examined, in a very perfect condition, in the skeleton of fish, caudal vertebra of crocodile, and thoracic vertebra of birds; and thus we are led up to the Mammalian form.

They are named as follows :—

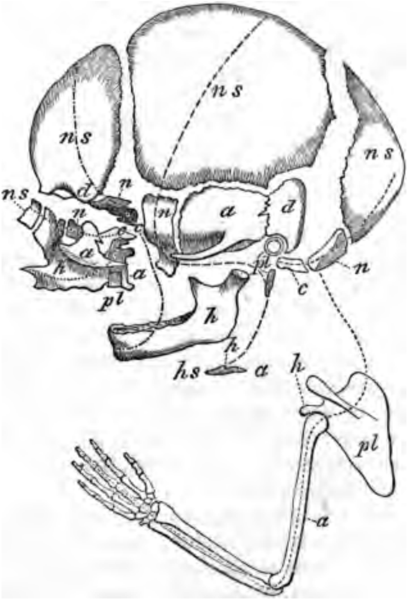


Neural spine; sometimes bifid, as in man's cervical vertebræ.
Zygapophyses; 4 articular processes, 2 to neural, 2 to hæmal arch.
Neurapophyses, 2; forming sides of neural arch.
Diapophyses, 2; upper transverse processes.
Centrum; the body, or most essential part.
Pleurapophyses, 2; ribs.
Parapophyses, 2; lower transverse processes.
Hæmapophyses, 2; forming sides of hæmal arch.
Hæmal spine; sometimes bifid.

The Ideal Vertebra.

These elements can be found, more or less modified, in cranial, cervical, thoracic, lumbar, pelvic, and caudal vertebræ of all skeletons. It is to be regretted that these names are so novel and apparently pedantic, but *Dr. Humphry* of Cambridge, in his philosophic treatise on the skeleton, has suggested much simpler expressions. A familiar example will illustrate the necessity for the suppression of some elements in certain parts of the human skeleton; thus, if the ribs or pleurapophyses of the lumbar vertebræ were developed, the abdomen would be as indistensible as the thorax.

Space will not allow me to describe what *Maclise* called "the archetype skeleton," and which has been constructed by *Owen* as an ideal type for that of all vertebrata. As shown by the next figure, in which the letters correspond to the last; the skull is composed of four cranial vertebræ—occipital, parietal, frontal, and nasal, corresponding to the four great ganglia, in which the brain is developed—viz., epencephalon, mesencephalon, prosencephalon, rhinencephalon, and the organs of the senses—hearing, taste, sight, and smell. I shall describe the homology of the first of these, as showing "the nature of limbs," a subject admirably reasoned on and proven, especially from the anatomy of fish and lepidosiren, in *Owen's* great work bearing that title. The centrum is seen in the basilar process, the neural arch in the foramen magnum, the neurapophyses in the portions at each side, and the neural spine in the expanded part behind. The condyles represent the zygapophyses; the hæmal arch is transferred to the side of chest, where, the student will be surprised to learn, it forms the upper extremity, the scapula being homologous to the pleura-



The Four Cranial Vertebræ.

pophyses, its coracoid process to the hæmapophysis, and the arm, a diverging appendage. *Maclise* regards the scapula and clavicle as belonging to the neighbouring cervical vertebræ.

The following are the elements of the four cranial vertebræ as represented in the foregoing figure :

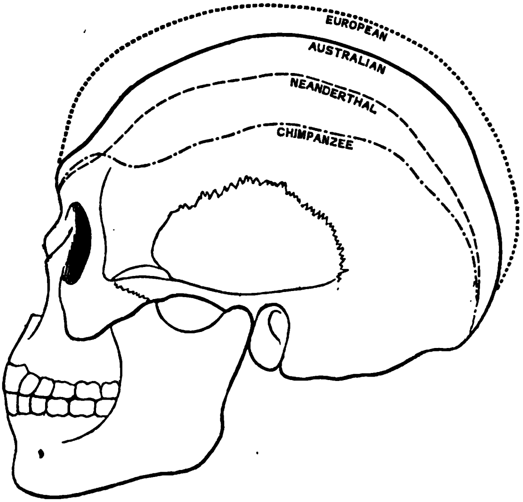
	OCCIPITAL.	PARIETAL.	FRONTAL.	NASAL.
Neural Spine.	All behind foramen magnum.	Parietal.	Frontal.	Nasal.
Neurapophysis.	All beside foramen magnum.	Great wing of sphenoid.	Lesser wing of sphenoid.	Lamella of ethnoid.
Diapophysis.		Mastoid process.	External angular process	
Centrum.	Basilar process.	Back of body of sphenoid.	Front of body of sphenoid.	Vomer.
Pleurapophysis.	Scapula.	Styloid process and stylo-hyoid ligament.	Tympanic process.	Palate bones.
(Diverging appendage).	Arm.	Thyro-hyoid ligament.		Internal pterygoid plate.
Hæmapophysis.	Coracoid process.	Lesser cornu of hyoid.	Lower jaw.	Upper jaw.
(Diverging appendage).				Malar and squamous.
Hæmal Spine.	Manubrium (which also belongs to first thoracic vertebra).	Body of hyoid.	Symphisis of lower jaw.	Premaxillary bones.

Maclise considers the facial bones, the hyoid and the thyroid, cricoid and tracheal cartilages, as parts of the hæmal arches of the corresponding cranial and cervical vertebræ, but the far greater number of tracheal rings than vertebræ throws doubt on the hypothesis.

Constancy in number is very remarkable throughout mammalian skeletons, of which the number of cervical vertebræ is a striking instance, there being but seven in the long-necked giraffe, and the same number in the whale, whose head, like that of fishes, seems directly set on the trunk. The three-toed sloth, where there are nine, and the sea-cow, where there are but six, are the sole exceptions. The same homology to the elements of vertebræ can be demonstrated in every bone of the body; hence the importance of the theory which *Holden* calls "the grammar of all osteology."

The Human Family is calculated to include about 1,000,000,000 individuals, the average duration of whose life is such that one dies about every second. The science of ethnology investigates the varieties of this vast multitude, and its difficulties will be understood when it is stated that no less than 3,064 distinct languages, and 1,100 religious creeds are now extant among them. Ethnological dynamics considers the influences which, working for centuries, have produced varieties among men. Among those that are physical are climate, soil, and food, besides which mental culture has remarkable influence. *Agassiz* remarks that all round the arctic circle, and thus, in every longitude there is as striking a similarity between the men as between the fauna and flora of each region. Such are the Laplanders, the Esquimaux, and the Samoiedes, on the European, American, and Asiatic continents respectively. Civilization produces many differences of individual physiognomy, for there is the closest similarity in the countenances of the members of any savage tribe. The effect of food in altering the characters of man has been painfully illustrated in our own country, for no one can have failed to remark how much the sad famine years depressed the physical and mental characters of the western and southern people, or how, under Providence, more prosperous times have again ameliorated their condition in both these respects. Sometimes, however, we cannot perceive the effect of such influences, acting for a short number of years, or in one generation, as the European, American native, and Negro, are found to preserve their distinctive characters under very similar circumstances. So gradual, then, are such changes, that many think it necessary to suppose a much earlier origin for the human species than usually assigned, as we find the Egyptian artists have pictured the characters of Hebrew, Copt, and Negro, as strongly marked in the Mosaic period as they are now. *Lepsius* asserts that the chronology of the Egyptians extends to 3,900 B.C., soon after which the building of the pyramids began; and the late *Mr. Horner* read a paper before the Royal Society in 1858, in which he stated that man has existed, and in a civilized state, for 13,370 years. He found a fragment of pottery 39 feet from the surface of the Nile; and as sediment is only deposited at the rate of 3½ inches in the century, it would have taken that vast period to have buried it so deep.

Fossil remains of man, coeval with the mammoth,



Outlines of European, Australian, and Neanderthal Skulls, and that of the Chimpanzee.

have been discovered by *Schmerling* in the cave of Engis, on the banks of the Meuse, and others by *Dr. Schaaffhausen* in a cavern on the Neanderthal, of greater antiquity, if we can judge from the deposit of dendrites. The latter was but a fragment, yet it indicated very low development in its flattened form, prominent supraorbital ridges, enormous frontal sinuses, and extremely small facial angle, which was calculated at 56° ; it may be, in fact, regarded as the most brutal of all known human crania. It nevertheless was of medium capacity, and immensely above the most anthropoid skull in this particular. *Mr. Busk* has described a skull from a tumulus at Borreby, Denmark, almost identical with the Neanderthal fragment.

Speaking of the origin of all from a common parent, *Dr. Symonds* most eloquently exclaims: "Does the Bosjesman—who lives in holes and caves, and devours ants' eggs, locusts, and snakes—belong to the same species as the men who luxuriated in the hanging gardens of Babylon, or walked the olive grove of Academe, or sat enthroned in the imperial homes of the Cæsars, or reposed in the marble palaces of the Adriatic, or held sumptuous festivals in the gay salons of Versailles ? Can the grovelling Wawa, prostrate before his fetish, claim a community of origin with those whose religious sentiments inspired them to pile the prodigious temples of Thebes and Memphis, to carve the friezes of the Parthenon, or to raise the heaven-pointing arches of Cologne ? That ignorant Ibo, muttering his all but inarticulate prayer—is he of the same ultimate ancestry as those who sang deathless strains in honour of Olympian Jove, or of Pallas Athenè—or of those who, in a purer worship, are chanting their glorious hymns or solemn litanies in the churches of Christendom ? That Alfouro woman, with her flattened face, transverse nostrils, thick lips, wide mouth, projecting teeth, eyes half closed by the loose, swollen upper eyelids ; ears, circular, pendulous, and flapping ; the hue of her skin of a smoky black, and (by way of ornament) the septum of her nose pierced with a round stick some inches long—is she of the same original parentage as those whose transcendent and perilous beauty brought unnumbered woes on the people of ancient story, convulsed kingdoms, entranced poets, and made scholars and sages forget their wisdom? Did they all spring from one common mother? Were Helen of Greece, and Cleopatra of Egypt, and Joanna of Arragon, and Rosamond of England, and Mary of Scotland, and the Eloïses, and Lauras, and Ianthes—were all these, and our poor Alfouro, daughters of her who was 'fairest of all her daughters—Eve?' The Quaiqua, or Sabo, whose language is described as consisting of certain snapping, hissing, grunting sounds, all more or less nasal—is he too of the same descent as those whose eloquent voices 'fulmined over Greece,' or shook the forum of Rome—or as that saint and father of the Church surnamed 'Golden-mouthed'—or as those whose accents have thrilled all hearts with indignation, or melted them with pity and ruth, in the time-honoured halls of Westminster?"

The identity of the varieties in the chief physiological functions, such as the length of utero-gestation, argues the origin of all men from a pair of common parents, for these vary much, even in species most closely allied—thus, the she-wolf carries her young ninety days, the bitch but sixty-two. The union, too, of individuals of varieties most widely apart, as European and Negro, is fruitful, as is also the progeny of such intermarriage. Now all hybrids of animals are sterile, at least after a second generation. Again, there is some resemblance between most languages—for instance, it is said the infants of all nations first pronounce the syllables *ba*, *pa*, *ma*. There are, of course, very great differences in such particulars as height, of which M'Grath, the Irish giant, whose skeleton is preserved in Trinity College Museum (8 feet 6 inches), may be regarded as an occasional excess; whilst the Patagonians, whose average height is 6 feet, and the Bosjesmen, who measure but 4 or 4½ feet, may be taken as national extremes. In other animals the range of size is much larger—for instance, it is stated the English dray-horse has been found 27 times larger than the Shetland pony. The hair of different nations affords data for classification—thus, the Melanocomous, or black-haired; the Zanthous, or yellow-haired; and the Leucous, or white-haired, may be distinguished. The last class, also known as Albinoes, occurs in any variety, even Ethiopian, and are marked by white skin, pale yellow hair, pink irides, and red pupils. *Draper* thinks the changes of colour which heat produces due to interference with the action of the liver.

The Cranium affords very evident distinctive characters, and it may be viewed in four aspects—1, Lateral, *Camper;* 2, Vertical, *Blumenbach;* 3, Basilar, *Owen;* and, 4, Front, *Pritchard.* The last-named author has described three well-marked varieties of skull, which broadly characterize groups of men—1, The oval or symmetrical; 2, The broad or pyramidal; and, 3, The elongated or prognathous. It must, however, be confessed that such conditions are not peculiar to any group, as many negroes have an oval, lofty skull, and many Europeans acquire the debased aspect of the prognathous skull, and *Tiedemann* asserts that the capacity of the skull of all varieties is equal, only differing in position of brain and face. *Morton* assigns 92, 83, and 72 cubic inches as the average capacity of the skull of Europeans, Negroes, and American Indians respectively. Before describing the varieties into which man is divisible, it is well we should understand the terms we use, and I select the definitions of *Dr. Latham,* as the most learned of living ethnologists and philologists: "A **species** is a class of individuals each of which is hypothetically considered to be the descendant of the same protoplast, or of the same pair of protoplasts. A **variety** is a class of individuals each belonging to the same species, but each differing from other individuals of the species in points wherein they agree amongst each other. A **race** is a class of individuals concerning which there are doubts as to whether they constitute a separate species, or a variety of a recognized one." Hence, no such word as race should be used in the natural history of man. In the present state of ethnological science, and in the absence of any physiological points of distinction, the following classification (of which *Cuvier* described the first three groups, *Blumenbach* the two last) may be considered as at least convenient.

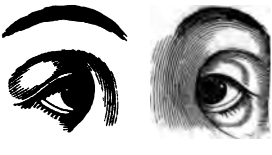
I. **Caucasian**, including all Europeans—except Finns—the natives of Western Asia and Northern Africa, of whom *Larrey* considered the Arabs the most perfect of men. It must be acknowledged that this class groups together many nations differing very widely, and the name might be restricted to the dwellers on or about Mount Caucasus, so long famous for personal beauty, and the Armenians. The characteristics are a fair, or sometimes slightly brown skin, but always letting the colour of the blood appear through; abundant, soft, wavy hair, generally dark; large orthognathous cranium, lofty forehead, with a small face placed under it; facial angle from 80° to 85°, narrow nose, thin lips, round and prominent chin. The eyes vary in colour, but always ex-

Caucasian—Sir A. Cooper.

press the emotions more truly than any other feature, in a way scarcely understood. The moral feelings and mental powers are capable of the highest elevation by the genial influence of education. To illustrate the characters of the variety, I have introduced a portrait of that able physiologist, greatest of surgeons, and true philanthropist—Sir Astley Cooper.

II. **The Mongolian,** including the natives of Central and Northern Asia, the Chinese, Japanese, and the Laplanders and Esquimaux, all of whom are nomadic, mainly equestrian, and often subjected to great privation. The variety is marked by an olive skin, dark eyes, black, strong, and straight hair, and scanty beard, low forehead, flat and broad face, especially at the glabella, or space between the eyebrows, prominent cheeks, oblique eyes, with the opening between the lids narrow, and drawn up at the outer canthus. Between the inner canthus and the nose there is often a semi-lunar fold, which surgeons may meet with under the term of epicanthus. *Sir W. Wilde* (from whose work on "Malformations of the Eye" the annexed representation is taken) states that it indicates some admixture of Mongolian blood.

Mongolian.

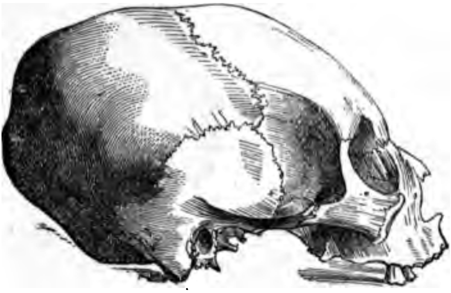


Epicanthus.

III. **The Ethiopian,** or natives of Africa, and their numerous descendants in the slave states. The skin and eyes are black, hair short, crisp, and woolly, with a fetid sebaceous secretion, so copious that it can be felted; skull very thick, prognathous, facial angle 70° to 75°, forehead low and slanting; jaws protruding; chin receding; nose broad and flat, spreading out on the cheeks; lips thick. The calf is very high, the bones of leg extremely convex; and the heel projecting, with a foot but slightly arched. It is said, but on very questionable authority, that the premaxillary bone is decidedly present. It will be remarked that there are few anatomical differences between the Negro and the more elevated races, much as they have been sought for by those who attempt to defend that disgrace to humanity—slavery. The president of the Anthropological Society surpasses any American pro-slavery advocate in his late address on the subject, which contains the following absurd and irreverent passage: "Thus, an anatomist, with the Negro and ourang-outang before him, after a careful comparison, would say perhaps that nature herself had been puzzled where to place them, and had finally compromised the matter by giving them an exactly equal inclination to the form and attitude of each other." *Lawrence* gives some examples of individuals of this race where the skin was white, and one instance where it became gradually white after the age of twelve. The person had a second attack of measles, and lost smell entirely. The face and other exposed parts assumed a copper tint. *Dr. Livingstone* states, that syphilis cannot be perpetuated among the Africans.

Ethiopian.

IV. **The American**, comprising all the aborigines, save the Esquimaux. The skin is of a dark red, hair black and long, beard small, skull and face very like the Mongol, but more elongated, as the figure of a Cherokee



Cherokee Skull.

skull shows, and the nose is larger and more aquiline. They are remarkable for the want of domestic animals, their active habits, and the great number of sections into which they are broken up. They are rapidly diminishing in numbers owing to the poison alcohol, which, however, it is reported, never produces delirium tremens. The variety spreads rather north and south, from the arctic region to Patagonia, and not in the same latitude and climate as other varieties do. One tribe, the Waraws, has been said to be "arboreal," since *Sir Walter Raleigh* recorded that "in winter they dwell upon the trees, where they build very artificial towns and houses; for between May and September the river of Orinocco riseth 30 feet upright." Dwellings are formed by docking the Ita-palm, and thence spreading out a floor.

V. **The Malay**, or Oceanic of *Latham*, including the natives of the Asiatic Islands, Borneo, Australia, New Zealand, &c. The skin is brown, hair black and copious, forehead narrow, but rather high; face prominent, lips thick, and mouth wide. The characters of the skull are exhibited in the figure of an Australian cranium, on p. 29. It is remarkable for the thickness of its walls and the frontal sinuses being often undeveloped. The physical strength and development of the Malay, especially in the pelvic extremities, is very low, and it may be questioned whether the variety does not rank below the Ethiopian in the human scale.

Bosjesman playing on the Gourah.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. State the species, genus, sub-order, order, and class of animals to which man belongs.
2. Explain what is meant by the "facial angle."
3. What are the most striking differences between the crania of man and the gorilla?
4. Enumerate the parts of the ideal vertebra.
5. How have human crania been divided?
6. Enumerate the varieties of man and the characters of the Ethiopian group.

SENIOR.

1. Enumerate the zoological characters of man.
2. What are the anatomical peculiarities of the human upper and lower extremities?
3. State the psychical attributes which distinguish man from the brute.

4. Write out the elements of the epencephalic vertebra, with their ordinary anatomical names.
5. Adduce facts and arguments proving the unity and antiquity of the human race.
6. What fossil human remains have been discovered?

CHEMISTRY OF MAN.

Of the 60 or 65 elements or simple bodies which compose the material world, about 15, or one-fourth, occur in the human body, being ingested in the form of animal or vegetable food. They are—

Elements.	Symbols.	Elements.	Symbols.
Oxygen	O.	Potasium	K.
Hydrogen	H.	Sodium	Na.
Nitrogen	N.	Calcium	Ca.
Carbon	C.	Magnesium	Mg.
Sulphur	S.	Lithium	Li.
Phosphorus	P.	Iron	Fe.
Silicon	Si.	Manganese (?)	Mn.
Chlorine	Cl.	Aluminium (?)	Al.
Fluorine	F.	Copper (?)	Cu.
		Arsenic (?)	As.

Of these, the first four occur so frequently as to be called essential, and the last four are so entirely accidental that they should be omitted. It will be seen that none of these substances are peculiar, so it must be in their mode of union that differences between organic and inorganic bodies exist. As none of these elements occur in the uncombined state, it will be more convenient to consider their products, which may be classified as, I. Inorganic; II. Unnitrogenized; III. Nitrogenized.

I. **The Inorganic Group** possesses a constant and definite chemical composition, being generally formed by the union of two elements, or two pairs of elements, in either single or few equivalent numbers. They are mostly crystallizable. Our knowledge of these substances is not exact, as incineration, by which they are obtained, expels the volatile bodies, and oxidizes many others. They may be subdivided into—1. Those that are mechanically useful; 2. Those that are chemically useful; and, 3. Those that are accidental, and of no apparent use.

1. **Water** (HO) is essentially necessary to maintain, by its solvent power, all the great functions of the body, and to it are due most of the physical properties of the tissues, such as pliancy or elasticity. Its evaporation also duly cools the surface. It forms more than two-thirds of the weight of the body, constituting in 1,000 parts, of epidermis 37, teeth 100, bones 133, muscle 750, brain 789—the vital endowment of any tissue appearing to be proportional to its amount of water. *Blumenbach* had a mummy which weighed but 7½℔. About 4℔. of water are daily ingested as food or drink, and egested as urine, sweat, pulmonary and alvine discharges, the amount of each excretion being often vicarious.

Phosphate of Lime ($8\ CaO,\ 3\ PO_5$), of which there are 5 or 6℔ in the body, confers hardness on nearly all the tissues. Enamel, which is so hard as to strike fire with steel, contains 885, bone 550, muscle 2·5, blood 0·3. It is kept dissolved by the alkaline albumen in the blood, and by biphosphate of soda in the urine. Lactic acid also will take up more than one-half its bulk of this salt. Rickets during dentition, and ununited fracture during pregnancy, are explained by the teeth and fœtus appropriating so much of this mechanically useful salt, which has also been found nearly absent in osteo-malakia.

Carbonate of Lime ($Ca\ O,\ CO_2$) is found in the skeleton (especially in that of invertebrates and in bony growths). It may be amorphous, as in bones; or dissolved in carbonic acid; crystalline, as in the ear-concretions. It is said to be absent in osteo-malakia.

Phosphate of Magnesia (2 Mg O, PO_5) usually accompanies phosphate of lime, which it exceeds in fæces, being introduced in the cereal grains. In typhus, the phosphate of ammonia and magnesia has been found adherent to the Peyerian patches.

Fluoride of Calcium (Ca Fl) was discovered in teeth and bones by *Von Bibra*, especially those that are fossil. *Liebig* found it in bones from Pompeii, and it exists in blood, milk, &c. Silica often occurs (perhaps accidentally) in blood, bile, and urine,

2. **Chloride of Sodium** (Na Cl) is the most important of the substances which are chemically useful, and is found in all the tissues, save enamel—vitreous humour 14, cartilage 11, blood 4·5, bile 3·5, urine 3, bone 2·5, and muscle 2. There are about 4 ounces in the entire body. It is introduced in the separate state with the food of all people, excepting the South Sea Islanders and some South Americans, who, however, live on a salt-water fish diet. Most aliments contain it, except perhaps muscle juice and yolk of egg—hence their insipid taste. Its uses are, to increase solubility of albumen, to prevent coagulation of the blood, to furnish hydrochloric acid for the gastric juice and soda for the bile, to aid in carrying the urea from muscle, and, lastly, is useful in the process of osmose by altering the specific gravity of the fluids. It is excreted by the urine, save in pneumonia, when it accumulates in the lung. Cattle require this substance, for, when denied it, they lose condition. One-fifth less is excreted than is introduced as food, probably being decomposed into chloride of potassium and phosphate of soda.

Carbonate of Soda (Na O, CO_2) occurs in the blood, keeping the albumen fluid, neutralizing acids, which may be formed in the body, and promoting the oxidation of organic bodies, especially sugar. It is obtained from the tartrates, citrates, and mulates in vegetable food, the organic acid being changed into carbonic acid.

The Alkaline Phosphates are found in such tissues where common salt is deficient, as blood cells, muscle, and yolk of egg. They render more soluble the earthy phosphates. They are contained in cereal grains. The want of these potash salts produces scurvy, and lime-juice, which *Sir G. Blane* showed was prophylactic, contains citrate of potash plentifully. The potash salts abound in muscle and blood-cells, the soda in blood-serum.

Sulphur is found in the protein bodies, the cuticle and its appendages, and most largely in the taurin of the bile and the cystin of the urine. It occurs in the sulphates in urine, and in the sulpho-cyanide of potassium in saliva.

Phosphorus is contained in all the protein bodies, in nervous matter, and as phosphates in all the tissues. *Liebig* denies that any uncombined phosphorus exists.

Iron is found in the free state in the blood, as a chloride in gastric juice, and a phosphate in the spleen. It is abundant in colouring matter, as that of bile, hair, &c. Iron is contained in such quantity that the French are said, after burning the body, to have made a mourning ring out of it. A small commemorative medal might be also struck.

3. Among those bodies which are accidental, are manganese, which accompanies iron in blood, hair, &c., especially, it is said, in Scotchmen, who use so much oats as food—that grain containing it rather abundantly. It exists also in the lettuce, asparagus, cauliflower, and other vegetables. *Orfila* believed that arsenic was a normal constituent, but it merely appears if introduced as medicine, when, being cumulative, it remains for some time in the liver. The same may be said of lead and copper, but the latter is constant in the livers of some molluscs and crustaceans. Iodine is said to escape in the human breath, except in the Genevese, who are so subject to goître.

II. **The Unnitrogenized Group** are of more complex nature. They are mainly derived from the vegetable kingdom, many of them crystallize, and all consist of carbon, hydrogen, and oxygen.

Starch occurs in the ventricles and grey substance of the brain, and in special-sense nerves, according to *Virchow*, but is probably a pathological product. It is ingested in great quantities in bread and vegetables; arrow-root, sago, salep from the orchids, and Irish moss, are nearly pure starch. In powder it may be known by crackling between the fingers; it is arranged in granules either single, as in the potato, or grouped in a capsule of cellulose, which substance escapes undigested. Starch diffuses, but does not dissolve in cold water, but hot water bursts its capsules, producing a gelatinous mass, which dries into an insoluble crust. Its solution gives the well-known blue colour with iodine. Starch itself is useless as food, but by taking two equivalents of water becomes sugar ($C_{12} H_{10} O_{10} + 2 HO = C_{12} H_{12} O_{12}$). This conversion occurs in seeds when germinating, or malting, in food by fermentation excited by salivin, or on boiling with dilute acid, by which the intermediate substances, gum and dextrin, are produced.

The Sugars are very soluble in water, from which they crystallize; by fermentation they yield carbonic acid and alcohol. Their general formula is $C_{12} H_{12} O_{12}$, and the following varieties only differ in the amount of water they contain:—Glycose, or grape sugar ($C_{12} H_{12} O_{12} + 2 HO$), lactose or milk sugar ($C_{12} H_{12} O_{12}$), hepatose or liver-sugar ($C_{12} H_{12} O_{12} + 2 HO$), inosite or muscle-sugar ($C_{12} H_{12} O_{12} + 4 HO$). Sucrose, or cane-sugar, and some others, do not occur in animal bodies. Sugar may be recognised by the following tests. *Moore's*—Add liquor potassæ; boil, and the fluid becomes a brownish red. *Heller* further states that a few drops of nitric acid develops the odour of burnt sugar. *Trommer's*—Add liquor potassæ, and then gradually a weak solution of sulphate of copper; at once a blue colour or slight blue precipitate is formed; boil for a few minutes, and the fluid becomes orange, and at last deposits an ochre-brown suboxide of copper, the sugar having abstracted oxygen from the sulphate of peroxide of copper. *Dalton* states that the organic constituents of urine, gastric juice, &c., interfere with this test by preventing the precipitation of the suboxide. They can be removed by filtering with charcoal. *Maumené's*—Soak white woollen cloth in solution of chloride of tin; when dry, dip it in the fluid to be tested, and heat it to 212° (as before the fire), and if sugar be present, a shining black spot will appear. Starch, however, gives the same appearance. Fermentation also indicates the presence of sugar. Add some pure yeast to the fluid in a test-tube inverted, and after a few hours carbonic acid is evolved; if a mercury bath be used, its amount in the top of tube affords a rough quantitative estimate. Alcohol is also formed, and the microscope shows the torula cerevisiæ, or yeast plant.

Sugar is found in the blood, especially that of the hepatic vein and the right side of the heart, in milk, in the liver abundantly, and in the urine in diabetes mellitus, as will be noticed hereafter. Inosite is a sugar discovered by *Scherer* in the muscular tissue of the heart, but as yet it has no physiological interest.

The Fats are the last unnitrogenized group we shall describe. They are composed of carbon, hydrogen, and oxygen in varying proportions, and these elements are arranged as a fatty acid and the base glycerin, or, according to some chemists, the oxide of lipyl. If the acid and base be separated, fat is not again formed by their mixture. Glycerin is a sweet, limpid fluid, which is separated when any other base (as oxide of lead in the making of litharge plaster) unites with the fatty acid. As it does not evaporate, it has been found most useful in pharmacy and medicine. Brain and yolk of egg are said to contain it free. Fats are insoluble in water, on which they float, but soluble in ether, boiling alcohol, volatile oils; they fuse by heat, unless so great as to decompose or inflame them, and they solidify by cold, becoming crystalline. They render paper transparent, and become rancid when exposed to air; volatile acids being formed by oxidation. Their great heating and lighting power is due to their abundance of carbon and hydrogen in proportion to oxygen. On adding an alkali, they saponify, or form a soap, which is therefore a compound of the fatty acid and soda in hard soap, potash in soft soap. The fat of bacon and cod liver oil are the only ones which saponify by the carbonates of alkali.

The following are the fats contained in the human body:—Stearin, a white, hard mass, soluble in boiling alcohol, from which it crystallizes in scales nearly square; it melts at 143°. It is contained in very minute proportion, indeed some analysts deny its presence. Margarin is softer, and crystallizes in beautiful radiating needles; it melts at 118°. The acid of margarin, margaric acid, has been found free in the fæces, in pus, and the fluid of ovarian dropsy. Olein is fluid to 25°, before which, however, it gives up the margarin, which it holds in solution, and which then becomes solid. The mixture of these bodies which form human fat is fluid at all temperatures above 40°. The great amount contained in the human body proves that it cannot be derived from the fat of food alone, and by feeding cows, bees, &c., on starch or sugar, and other food carefully deprived of fat, it was found to be produced from these aliments.

Lipoids are substances which differ from fats in being non-saponifiable. They are cholesterin and serolin. Cholesterin (C_{28} H_{24} O) crystallizes in white rhombic scales. It is tasteless and inodorous, and requires a heat of 293° to fuse it. It exists sparingly in the bile dissolved by choleic acid, and abundantly in gall-stones. It is found in blood, nervous matter, fæces, and meconium, and in the following products of disease :—Pus, tubercle, many tumours, especially encysted, hydrocele fluid, atheroma of arteries, and cataract.

Serolin, once regarded as peculiar to the serum of blood, is probably but a mixture of ordinary fat and albumen.

III. We now have to consider the nitrogenized substances, which include most of the proximate principles, as they are called, rather vaguely, in contradistinction to the "secondary organic compounds," such as urea, which are mostly discharged with the excretions. They do not crystallize, which *Prout* regarded as characteristic, as that condition is produced by inorganic forces. They are complex, having four elements, hence called quarternary, and of these many equivalents. From the weak affinities of their nitrogen, they yield easily to decomposition, which can be prevented, as in the preserving of meat, by exclusion of oxygen by air-tight cases, by salt, which abstracts water, by sugar, creasote, &c. The tissues which they make in the living body are always undergoing a destructive oxidation, somewhat like eremacausis, or slow combustion, a more active change being resisted by the nitrogen they contain and by the conditions of life. Thus they may be called "noble" in the same sense as the term is applied to gold. Their chemical inertness may depend on their strong resistance to diffusion. By putrefaction, which is hastened by the contact of putrid matter, they evolve carbonic acid, nitrogen, ammonia, and sulphuretted, phosphuretted, and carburetted hydrogen. All the nitrogenized bodies give an intense red colour on being heated with a solution of mercury in nitric acid. This is *Millon's* test. The first group are the albuminoids, or protein bodies, so called from their chief importance by *Mulder*, who described them as compounds of a body he named protein, and varying amount of sulphur and phosphorus. He obtained protein by boiling any of these bodies with caustic potash, which removed the sulphur, and phosphorus. He assigned its formula as $C_{36} H_{25} N_4 O_{10} + 2 HO$. His view has not now many supporters, and protein is rather a product of decomposition than a base of organic bodies.

Albumen is found in serum of blood, lymph, chyle, the fluids of the cavities, and in pancreatic juice alone, of the secretions; also in the substance of brain and solid organs. Its most familiar form is white of egg. It varies much in these situations from the amount of alkali, salts, or fat combined with it. It is always fluid, and is kept so by an alkali, especially soda, which forms 1·58 per cent. of white of egg. Pure albumen consists in the 100 parts, of carbon 52·97, hydrogen 6·81, nitrogen 15·11, oxygen 23·54, sulphur 1·57, phosphorus 0·4 The tests are its coagulation by a heat of 160°, or more, according to the amount in solution; nitric, hydrochloric, or sulphuric acids; the latter stains albumen a deep purple; also by bichloride of mercury (hence its antidotal powers, as discovered by *Orfila*, in poisoning by that salt), ferrocyanide of potassium, in an acid solution, and some other reagents. It coagulates in flakes if the solution is neutral, as a milky cloud if slightly alkaline; and if strongly acid or alkaline, the solution forms, on evaporating, a colourless skin on the surface which was formerly thought to be peculiar to casein. Albumen is remarkable for its very low diffusive power, especially in its usual alkaline state, and thus it takes forty-nine times as long to pass through an animal membrane as hydrochloric acid, and in a given time over twenty times as much chloride of sodium will diffuse. This property is of vast advantage in retaining the blood and serous fluids within their proper vessels. Albumen has been at one time considered allied to the acids, at another to the bases, and thus its precipitation has been accounted for; but this occurrence is due undoubtedly to the acid or salt added being a crystalloid, and thus, being more soluble, it displaces the albumen. Its chemical inertness is one of its most useful physiological properties.

Fibrin is found in blood, lymph, chyle, and in many products of disease, as dropsical effusions, tubercle, and false membrane. It is known readily by its spontaneously becoming solid when it is found to be fibrillated, or arranged in interlacing threads. The membrana putaminis from the egg-shell exhibits this microscopic appearance best. When gelatin is precipitated by metaphosphoric acid, a substance exactly like fibrin results. In weak solutions, as hydrocele fluid, it does not separate spontaneously, but will do so when a piece of solidified fibrin is placed in the fluid. It may be obtained by whipping blood, washing the clot, or by filtering frog's blood, as the cells, being large, are held back.—(*Müller*.) Fibrin may be distinguished from albumen by not dissolving, but swelling and becoming transparent and jelly-like when digested in water containing a little hydrochloric acid, by dissolving in a weak solution of nitre, by decomposing the deutoxide of hydrogen, and by more rapidly putrifying. Its composition is not exactly known, but it is said to contain more oxygen than albumen, from which it is produced by oxidation. Whether it is a material for the formation of tissue, or a product of their destruction, as also the effect of ammonia in keeping it fluid, will be noticed in the chapter on "Blood."

Syntonin, or muscle-fibrin, was shown by *Liebig* to be different from blood-fibrin, for it does not dissolve in solution of nitre, but does so in that of hydrochloric acid. From albumen it differs in being precipitated from an alkaline solution, by common salt. It is found in voluntary and involuntary fibres, and in muscle cells, as those of the spleen and arteries.

Casein occurs in milk, fluid of thymus and allantois, yolk of egg, and in the blood, especially of suckling women. It differs from albumen in not being coagulable by heat, when, however, it forms a tough skin on the surface of the fluid if freely exposed to oxygen, while the weaker acids (acetic, lactic, &c.) and rennet precipitate it.

Globulin from the blood cells, and crystallin from the lens, differ but slightly from other protein bodies.

Salivin, pepsin, pancreatin, and other animal ferments, are supposed to be modifications of albumen, probably undergoing decomposition. They will be noticed hereafter.

Pyin, obtained by *Güterbock* from pus, is according to *Mulder*, a tritoxide of protein.

Gluten is abundant in the food of man derived from the cereal grains. It was discovered by *Beccaria*, who, from its ready putrefaction, its odour when undergoing that process, and its importance in food, regarded it as identical with albumen. It may be obtained by washing the starch out of dough, when it remains as a tough, elastic mass.

Legumin is another protein body contained in peas, beans, &c. It has the greatest proportion of phosphate and is most analogous to casein. From peas the Chinese make a food, taofoo, hardly distinguishable from cheese. The nitrogenized substances which follow are supposed to be derived from the protein bodies by some change, probably regressive.

Gelatin is obtained by boiling bones (ossein), cartilages, (chondrin), skin, fibrous tissue, and other structures whose use is mechanical, as the passive organs of locomotion. Isinglass, from the swimming-bladder of fish, is the purest example. It is soluble in boiling water, and " sets" into a jelly on cooling, if it be in proportion of 1 per cent. This jelly, when heated, becomes fluid, and sets again, but this cannot be repeated more than four or five times. Tannic acid, alcohol, bichloride of mercury, &c., precipitate gelatin. Chondrin, or that from cartilage, is thrown down in addition by hydrochloric and acetic acids, by acetate of lead, alum, and sulphate of iron. The tissues of old animals give a firmer jelly than those of young ones, as they contain less water chemically combined.

Elasticin, or the matter of yellow, fibrous tissue, is remarkably insoluble. Boiling for thirty hours at a temperature of 320° (as in *Papins'* digester), produces a brown solution, which does not set on cooling. The matter of the elastic layers of cornea, capsule of lens, and other transparent membranes, including probably cellulose, have similar properties.

Keratin occurs in hair, nails, hoofs, whalebone, &c., and is said to contain 6 or 8 per cent. of sulphur. It dissolves in alkalies and mineral acids. Dried mucus contains a similar body, mucin. The last group are the colouring matters.

Hæmatin ($C_{44} H_{22} N_3 O_6 Fe.$, *Mulder*) is the red pigment of the blood. It dissolves in alcohol, containing hydrochloric acid, or alkaline solutions, which brighten its colour. It absorbs oxygen, becoming a brighter red, and evolves carbonic acid. The matter containing iron which the spleen yields, and hæmatoidin from old extravasions, are modifications of hæmatin.

Biliphæin, or bile-pigment, is brown, but changes by oxidation to green. It is abundant in biliary calculi, and in jaundice, in urine, blood, the fluids of eye, and sometimes in saliva and sweat. It is probably formed from blood pigment, as bilifulvin, a variety of bile pigment, is identical with hæmatoidin. The green matter discharged when the liver is excited by mercurials is similar to hæmatin, and the effect of this medicine in destroying the colour of blood is well known.

Urophæin, or urine pigment, is little known. *Harley* finds it always contains iron, and believes it to be altered hæmatin. The difference of tint will not be objected when one remembers the change of colour blood undergoes in being absorbed from a bruise.

Melanin, or the colouring matter of hair, choroid, skin, and some morbid products, is another nitrogenized substance. Indican, a blue precipitate, identical with indigo, has been found in the urine, especially in Bright's disease, and in pus.

There are other substances in animal chemistry indefinately termed "extractive matter," alcoholic or aqueous, according to the solvent. Among those hereafter will probably be discovered many bodies of interest.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Enumerate those elements which compose the human body and their symbols.
2. What chemical uses does water fulfil in man's body?
3. Say what you know regarding the physiological chemistry of common salt.
4. Explain the change which starch undergoes when ingested.
5. State the composition of the fats.
6. Enumerate the so-called protein compounds, and the situations in which each occurs.
7. What substances analogous to fibrin and casein can be obtained from the vegetable kingdom?
8. What are the properties of gelatin?

SENIOR.

1. What arrangements of the chemical constituents of the human body have been made?
2. What tissues contain phosphate of lime in greatest abundance, and how is it conveyed to them?
3. Under what circumstances have accidental elements been found in the human system?
4. Enumerate the varieties of sugar found in the human body, and the tests of their presence.
5. Give the characteristics of the albuminoids.
6. State the differences, physical and chemical, between albumen and fibrin.
7. Contrast the chemical features of white and yellow fibrous tissues.
8. What chemical components of the human body contain iron most abundantly?

DIGESTION.

Every vital action is attended with destruction of tissue, the materials of which are then excreted. Now, this loss is made good by food, which is prepared by the process, or rather series of processes, we call digestion.

Food.—The amount of matter which is constantly changing in the human body is enormous, as may be learned from the fact that about 800℔ of solid food, 1,500℔ of fluids, and about 800℔ of oxygen, which is gaseous food, are annually ingested. The total, over 3,000℔, or about a ton and a-half, exceeds the weight of the body twenty times, and we surmise from this that the whole system is renewed in considerably less than seven years, the period assigned by the older physiologists. Before describing the nature of animal food, it may be stated that it is all produced originally by plants, which elaborate their tissues from inorganic matter. The functions of those two classes of organic beings are well contrasted in the following table arranged after *Prof. Galloway*:

A VEGETABLE	AN ANIMAL
IS	IS
AN APPARATUS OF REDUCTION;	AN APPARATUS OF OXIDATION;
Is fixed;	Possesses the faculty of locomotion;
Evolves oxygen;	Absorbs oxygen;
Absorbs heat and electricity	Evolves heat and electricity;
Decomposes carbonic acid,	Produces carbonic acid,
„ „ water,	„ „ water,
„ „ ammonia;	„ „ ammonia;
Produces organic substances;	Consumes organic substances;
Transforms inorganic matters into organic matters;	Transforms organic matters into inorganic matters;
Derives its elements from the earth and air.	Restores its elements to the earth and air.

From the soil, then, through plants and animals, there is always occurring a circulation of matter. Animals therefore derive their food either from the vegetable or animal kingdoms, or from both, and are thus divisible into herbivorous, carnivorous, and omnivorous, or more correctly amphivorous, to which latter class, as we shall find, man belongs. Domestication, has however, the effect of changing the food of animals; for instance, the cat can be altered from a carnivorous creature to one living wholly on vegetable food, the substitution being attended with remarkable change of habit, the fierce tiger-like wild-cat becoming our harmless fireside companion. On the other hand, however, herbivorous animals can be seldom brought to eat flesh.

Prout divided food into four groups—aqueous, saccharine, oleaginous, and albuminous. The first, with some other substances, belongs to the inorganic kingdom, the others to the animal or vegetable. The second and third groups are usually placed together as nonnitrogenous, respiratory, or calorific food, and the last is termed nitrogenized, plastic, or histogenetic. We shall, for convenience, adopt their division by *Liebig*, into respiratory and plastic—premising that all the pabulum for respiration and animal heat is not afforded by the food just ingested, a considerable portion being produced by the combustive destruction of tissues. In describing these groups of food, we must refer for chemical details to the last chapter.

I. **Respiratory Food** includes starch, sugar, the pectine bodies, fats, alcohol, and the aliments which contain them. Starch, as such, cannot be assimilated, but is changed into sugar mainly by saliva. Sugar may be still further changed into fat. It is thus that Negroes become so fat during the sugar season, when they consume it plentifully. The same race disproves the popular error that sugar injures the teeth, for theirs are remarkably white and sound; indeed, by producing lactic acid, it would cleanse the teeth, removing tartar, which is mainly composed of phosphate of lime. Moreover

Tomes found that teeth were not acted on by prolonged maceration in solutions of sugar.

Fats are plentifully partaken of by man, the more so the colder the climate is; and every one has heard of the appetite of the northern races for oily food. *Sir John Franklin* relates that he tried how much fat an Esquimaux boy could consume; after devouring 14℔ of tallow candles, he finished with a piece of fat pork, with which *Sir John* closed the experiment, feeling apprehensive for his store. Even children of five or six months old, influenced by hereditarily transmitted habit or imitation, will devour blubber with avidity, as witnessed during his residence in Greenland, by the late Sir Charles Gieseckè, Professor of Mineralogy in the Dublin Society. The rarity of phthisis in these climes may be due to this peculiarity in diet. The percentage of fat in some foods is very great, in others small—thus, pork, 30 to 50; mutton, 40; beef, 30; cheese, 25; veal, 16; herring, 6; goat's milk, 5·0; cow's milk, 3·5; human milk, 3; sole, 0·25.

Alcohol in some form enters into the diet of nearly all nations. Rice (arrack), milk (kumiss), honey (mead), juniper berries (gin), grapes (wine), cereal grains (whiskey, beers), are some of the substances which are used to obtain it by fermentation. Its formula is $C_4 H_6 O_2$. Being so rich in carbon, it would appear to be suited for a heat-giving food, a view supported by *Liebig*, *Moleschott*, and other chemists, for the following reasons:—It is easily oxidised out of the body; those who use it take little other calorific food; and it is not rapidly or freely thrown off by pulmonary or cutaneous surfaces. If such views be correct, it economises the tissues, for after its ingestion less carbonic acid is evolved, and hunger does not return so soon, a fact which travellers are aware of. It quickens the circulation, which may account for its diffusing warmth, and excites the brain, so that no practical physician neglects to avail himself of its stimulant powers. The most instructive experiments are those of *Dr. Hammond*, Surgeon-General of the United States army, who shows that it produces a daily gain of weight, being therefore a useful substitute for deficient food ; but being injurious if food be abundant, and the excess not got rid of by increased exercise, &c. He concludes "that alcohol increases the weight of the body by retarding the metamorphosis of the old and promoting the formation of the new tissues, and limiting the consumption of fat."

Those who object to its use, such as *Carpenter*, argue— 1. That it precipitates, and does not, like water, dissolve aliments and animal juices; but free dilution and perhaps partly the condition of albumen, as peptone, obviate this. 2. That, as many do not use it, it cannot be necessary. 3. That as a heat-giving agent, it is inferior to fat; some chemists and arctic voyagers assert this. 4. It cannot form azotised tissues or fat. 5. If it stimulates, an equal re-action occurs, so that nothing is gained. It acts as a poison in large doses, and in habitual small ones injures the nervous system, and produces, by a fermentible state of blood, liability to zymotic diseases, and other effects of chronic alcoholism. It is absorbed from the stomach, through the veins passes to the liver, which it often inflames; and it has been destilled as an inflammable fluid from the brain. *Ecker* states that it is by considerably delaying the cerebral circulation it produces its intoxicating effects. Thein, the active principle of tea, coffee, &c., has physiological effects somewhat similar to alcohol, being also an arrester of metamorphosis. It is stated to be the most highly nitrogenized of vegetable substances by *Sir R. Kane* (who assigns to it the formula $C_8 H_5 N_2 O_2 + Aq$); yet it is rapidly excreted as urea without fulfilling any plastic office.

II. **The Plastic Group** includes the albuminoids we obtain from the animal and vegetable kingdoms. From the similarity of flesh used as food to that of the living body, it is readily assimilated, and thus the more carnivorous the animal, the shorter and more simple is the alimentary canal. The relative amount of nitrogen in various foods, which shows, though not exactly, their relative nutritive power, is given in the following table, milk being taken as a standard of 100:

Rice	81	Cow's milk	237
Potatoes	84	Yolk of egg	305
Oats	138	Salmon	610
White bread	142	Flounder	954
Brown bread	166	Pigeon	827
Peas	239	Mutton	852
Beans	320	Beef	942

The heat-giving value of these aliments is nearly the reverse of their flesh-forming. *Liebig* calculates that if 100 parts of fat produce a certain amount of heat, it will take 240 of starch, 249 cane-sugar, 263 grape-sugar, and 266 of alcohol (50 per cent.) to produce an equal amount. The ultimate composition of blood and flesh is identical; hence it is to be regretted that so much food is lost in the killing of butcher's meat, the blood not being preserved; and meat of a most superior character was obtained by *Dr. Carson's* plan of killing animals without loss of blood. Flesh from which the alkaline blood is wholly extracted, for instance bled veal, is very unwholesome, as the acids in the muscle then preponderate and is most likely to produce scurvy. I have treated fully of this subject in my "Papers on Public Health," and have suggested some other modes of slaughtering. Vegetarianism is abundantly refuted by the truths of anatomy and physiology; man's teeth, digestive organs, and his habits and circumstances in various climates, clearly showing the necessity for a mixed diet. Many experiments since the time of *Haller* (despite the example of *Shelley* and *Rousseau*, whose main argument was that both the human species and herbivora had two breasts) have proved the folly of a purely vegetable diet. Among the cases of complete aversion to animal food may be mentioned that of the Abbé de Villedieu, who is said to have died in consequence of having taken some for the first time when 30 years of age. Besides the animals we slaughter, horse-flesh and ass-flesh are now extensively used on the Continent, and *Prof. Owen* has recommended the introduction of the eland.

The processes of cooking effect many changes on flesh; that of roasting is the least injurious, as the sudden heat coagulates the surface of the meat, and produces a crust which retains the juices of the flesh. It also converts the fibrous tissue into gelatin, and bursts the fat cells. In boiling meat, *Liebig* advises that it should be put at once in boiling water, to form a similar coagulated crust, the meat within then closely resembling that roasted. If our object be to make soup, the reverse plan must be adopted—viz., putting the meat in cold water, and then slowly raising the temperature. The strongest extract of beef, or "liquor carnis," is obtained by dividing lean meat very minutely, adding but enough of water to moisten the meat, and heating by water placed outside the vessel containing it. A still better soup may be obtained by adding about 12 drops of hydrochloric acid, and about 40 grains of common salt, to the pound of chopped meat, and digesting in about 2½ pints of cold water. It must be taken cold, or never heated above 120°, and there is thus introduced a solution of uncoagulated albumen. The uselessness of soups, as ordinarily prepared, should be made known, as much error prevails. They are mostly solutions of gelatin, which substance the French and Dutch "Gelatin Commissions" proved has no plastic and little respiratory value, and is cast off in very considerable quantity in the urine. By boiling meats, much salts are abstracted, and should be restored by the use of vegetables. Their use lessens the phosphates and increases the carbonates in the blood—hence their influence, as every physician knows, in calculous diseases. They are especially necessary with salted meat, as the potash has been thereby extracted. That flesh should be untainted is shown by the fearful mortality among the Färoese (who eat decomposed food) when they are attacked by measles or other zymotic diseases, and by the poisonous nature of putrid sausages.

The necessity for a Mixed Diet, combining the nitrogenized and unnitrogenized groups, might be premised from the complex nature of the animal body, and is shown by many diseases being produced by the want of any element of food, and by the well-known experiments of *Magendie*, who fed dogs on sugar, starch, gum, fat, &c., and found they died in about 31 days—indeed almost as soon as if wholly starved. The first part which sloughed was the cornea, as it was the least vascular, yet contained much nitrogen which the food could not supply. Very similar effects were produced in the case of *Dr. Stark*, who abstained entirely for four months, from nitrogenized food. He was attacked by emaciation and diarrhœa, and sank a victim to his mis-directed physiological zeal. *Dr. Budd* informs us the Hindus, who feed almost entirely on rice, are often attacked with sloughing of the cornea. Many foods are presented to us by nature, or produced by an art so universal as to be almost natural, in which the various elements of food are duly combined. The egg, milk, and bread, are such perfect alimentary types. In the egg, the yolk containing much fat represents the respiratory class; the white is the type of all plastic food, while water and salts are also present in due proportion. Of milk, and the fat, sugar, casein, water, and salts, contained in it, we shall speak hereafter, and it will be seen that the heat-giving material exceeds, as young animals require and produce abundant warmth.

In Bread, so justly termed "the staff of life," are combined starch, gluten, water, and salts, the oleaginous alone, of all the constituents of food, being absent, but readily supplied by the addition of butter. Bread is of two kinds—1. Vesiculated or spongy, which is superior, mainly by exposing a greater surface for the action of the saliva; and, 2. Unvesiculated or solid, as in the form of biscuit, pudding, and the unleavened bread of Scripture. Vesiculated bread is either fermented or aerated. The former, which has been the staple food of nearly all the world for centuries, is made by mixing the flour with some ferment or catalytic, such as yeast, a substance containing gluten, obtained in brewing. The gluten and starch are both acted on, some of the latter being converted into sugar, and further into carbonic acid gas, which makes the bread light and spongy, and alcohol. The quantity of alcohol produced by panous fermentation is very inconsiderable, yet a bread-making company was started in London, which proposed to collect it. How unpopular this became was shown by the announcement in many shop windows of "Bread sold here with the gin in it." The bread was dry and tasteless, and the project failed. Lime water has been proposed by *Liebig* in bread-making, as it preserves the tenacity of the gluten. It has been stated untruly that a large proportion of the starch is wasted in making bread by fermentation.

Aerated bread is made by forcing carbonic acid into it, either by mixing carbonate of soda with the flour, and wetting this with water containing hydrochloric acid; carbonic acid is thus evolved, and common salt retained in the bread—or by *Dr. Dauglish's* process, which is as follows: the flour is wetted by water saturated with carbonic acid in the same way as soda-water; the dough thus made is moulded in tin cases, and the carbonic acid, driven off by heat, renders the bread spongy. The whole process is conducted by steam, and is completed in twenty minutes. Besides ensuring greater cleanliness, the making of bread by machinery saves time, and tends to improve the sanitary and moral conditions of the bakers, a subject which has attracted much attention lately. Brown bread has been long considered "wholesome," the bran containing gluten and a ferment which converts starch into sugar, the bread being thus more rapidly digestible. The insoluble matters stimulate the bowels and prevent constipation. Stale differs from fresh bread more in the arrangement of its molecules than in the amount of water, for bread loses but $\frac{1}{100}$ of its water in five days; it will get stale in moist air, and become fresh again by being placed in the oven, where water must be driven off.

The principles of Dietetics may point out approximately the proper quantity of food, but no exact standard can be fixed, individuals varying so much under the influence of habit, climate, labour, &c. The following is the diet scale of the British navy: "There shall be allowed to every person the following quantities of provisions: bread 1 ℔, beer 1 gallon, cocoa 1 oz., sugar 1½ oz., fresh meat 1 ℔, vegetables ½ ℔, tea ¼ oz. When fresh meat and vegetables are not issued, there shall be allowed, in lieu thereof, salt beef ¾ ℔, and flour ¾ ℔, alternately with salt pork ¾ ℔, and pease ½ pint, and weekly, whether fresh or salt meat be issued, oatmeal ½ pint, vinegar ½ pint." The following dietaries are given (on the authority of *Playfair*) in ounces per week:

	Total.	Nitrogenous.	Unnitrogenous.	Carbon.	Mineral.
English soldier ...	378	36·15	127·18	71·68	4·92
French soldier ...	347	32·24	127·76	85·25	4·62
English prisoner,	206½	15·28	111·85	59·23	3·46
Bombay prisoner,	182	28·00	101·50	68·81	2·03

The following are the articles of the diet-table of the military hospitals:

LOW.			HALF.		ENTIRE.	
Meat, .	8 oz.		Meat, .	8 oz.	Meat, .	12 oz.
Bread,	14 ,,		Bread, .	16 ,,	Bread, .	16 ,,
Salt, .	½ ,,		Potatoes,	8 ,,	Potatoes, .	16 ,,
Tea, .	¼ ,,		Barley, .	1½ ,,	Barley, .	1½ ,,
Sugar,.	1½ ,,		Salt, .	¾ ,,	Salt, .	¾ ,,
Milk, .	6 ,,		Tea, .	¼ ,,	Tea, .	¼ ,,
Butter,	1 ,,		Sugar, .	1½ ,,	Sugar, .	1½ ,,
Rice, .	2 ,,	Pudding.	Milk, .	6 ,,	Milk, .	6 ,,
Milk, .	¼ pint		Vegetables,	4 ,,	Vegetables,	4 ,,
Sugar,	½ oz.		Butter, .	1 ,,	Butter, .	1 ,,
Egg, .	1 ,,		Flour, .	¼ ,,	Flour, .	¼ ,,

As dietetic extremes, may be mentioned the Esquimaux, one of whom, *Captain Parry* states, consumed 35 ℔ of solid food in 24 hours; and *Cornaro*, who subsisted for 58 years on 12 oz. of food, and 14 oz. of light wine daily. Nature's promptings, if attended to, afford the surest guide, the more so if repletion be prevented by allowing due periods for the acts of mastication and other preparatory processes—when the system has time to intimate, by the feeling of satiety, that its wants have been supplied.

The time of meals must vary much with habit and ranks of life, but at least sufficient interval should elapse between each meal to allow stomachic digestion, and the processes which follow it, due time. In children, waste and repair of tissue is more rapid, and the intervals between meals should be shorter. It has been calculated, that while an adult consumes daily 43½ grs. of carbon and 1¾ grs. of nitrogen for every ℔ of his weight, an infant requires 136 of carbon and 10⅔ of nitrogen. In them, also, the appearance of each class of teeth suggests a change of food—thus, flesh may be given when their canine teeth are developed.

Before describing the processes to which food is subjected, we will briefly discuss the symptoms which indicate that it is required—namely, hunger and thirst.

Hunger is a feeling, varying in degree from the agreeable promptings we call "appetite," to the horrors of "starvation." It becomes an important social question, when it is remembered that it may be regarded as a great stimulus to human labour, or a powerful incentive to crime. Its dependence on the waste of tissue is shown by its greater force and more rapid recurrence in young animals, and those who consume much oxygen, than in the cold-blooded and hybernating classes. The proximate cause of hunger would seem to be some influence on the branches of the pneumogastric nerves, for *Brachet*, after letting a dog become ravenously hungry, divided these nerves, and the animal lost all desire for food. This experiment, however, in the hands of *Reid*, yielded somewhat different results. Narcotics, also, destroy appetite, by acting on the nervous system. *Beaumont* believed that it was produced by gastric juice being retained in the follicles, and pressing against the nerve-filaments. However, that fluid is not secreted during fasting, and the first portion of food would empty the follicles, yet does not appease hunger. Others regard it due to the scanty supply of blood the organ receives during fasting. The feeling is sometimes subjective or dependent on conditions of the nervous system itself; and, again, the effect of the depressing passions on it is well known. Although mainly a systemic indication, mechanical distention of the stomach will relieve hunger, as by the introduction of clay, which many races are said to resort to. Want of food is then indicated by a sinking sensation about the gastric region, general faintness, and the secretion of gas. If such promptings are not attended to, the prostration increases, the lymphatics absorb greedily, the individual feeding on himself, the voice becomes feeble, the eye sunken, yet terribly brilliant and wild, and the agonies of starvation are established; animal heat falls rapidly, delirium occurs, and death takes place about the fifth or sixth day, or as soon as the loss of weight amounts to two-fifths. Life will be sustained much longer under the influence of syncope, hysteria, hallucination, and other nervous diseases.—Instances of prolonged fasting are much exaggerated, and are generally cases of imposture, having deceived, however, such careful observers as *Berard*, *Burdach*, &c. *Sloane* relates that a man was rescued alive from a coal-mine after being confined 23 days, during which he took nothing but some foul water for the first 10 days. It is stated that the stomach is unable to digest, and that loathing for food occurs some days before death.

The well-known experiments of *Chossat* on starvation prove that the tissues waste in the following order, and most rapidly as death approaches: the adipose, muscular, osseous, and nervous. The slowness with which the nervous matter wastes is remarkable, remembering the large amount of fat it contains, and may depend on the difficulty of absorption through the neurilemma of the tubes. After death, the stomach and intestines are found shrunken, rugous, and extremely thin, the gall-bladder over distended, the bile not being used or neutralized; the other secretions and blood are found scanty. The rule that death occurs when the loss amounts to two-fifths, holds good for nearly all animals, yet the time of death varies remarkably, birds succumbing within a week, and if *Rudolphi* can be credited, the proteus living five years without food. Another exceptional case was reported to the Linnean Society, where a pig lived 160 days, buried under a chalk bank, having lost 75 per cent. of its weight, chiefly fat. As the introduction of new matter by food helps to expel the effete matter of the tissues, starvation kills partly by the retention and decomposition of this matter producing a form of putrid fever, and putrefaction rapidly occurs after death. The connexion between want of food and zymotic diseases is admirably shown in *Dr. Corrigan's* essay on "Famine and Fever as Cause and Effect in

Ireland." The curative effects of food in the disease was forcibly taught by *Dr. Graves*, who wished that his epitaph might be, "He fed fevers."

Thirst, although marked chiefly in the mouth and pharynx, is a systemic sensation, as the injection of water into the veins or the stomach will relieve it. *Bernard* has shown this by producing a gastric fistula in a dog; the animal drank incessantly while the fistula was open, as the water was not absorbed, but was satisfied with a small quantity when it was closed. In the words of *Mayo*, "a person might be hungry without a stomach, and thirsty without a throat." Even a moist air, or bathing, will slake thirst—hence the renowned *Franklin* advised sailors, when the supply of water fell short, to bathe and to damp their clothes. This practice is not safe if food also be insufficient, as it tends to lower animal heat, and should now be unnecessary, since *Dr. Normandy's* process of separating pure water from sea-water by destillation has been adopted. The sensation of thirst would seem sometimes to be absent, as *Sauvages* relates of a member of the Toulouse University.

The feeling may be subjective, and spices and stimulants applied to throat will produce it, although there is no want of water in the system. The symptoms of thirst are a dryness and clamminess of the mouth and pharynx, the tongue feels as if sticking to the palate, respiration is obstructed, and nervous irritability is heightened to an extreme degree. The blood cells have been found shrivelled by exosmose of their water. Death occurs sooner than from deprivation of food, and with even greater distress, as seen in some of the persons confined in the black-hole of Calcutta. Ice and, what is remarkable, tepid water are superior to equal quantities of cold water for slaking thirst, as we see in fevers and diabetes. Thirst kills by exciting pyrexia.

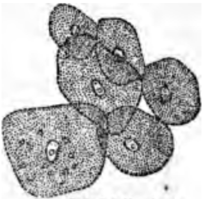
The Stages of Digestion were, according to *Magendie*—1. Prehension; 2. Mastication; 3. Insalivation;

4. Deglutition; 5. Action of the stomach; 6. Action of the small intestines; 7. Action of the large intestines; and, 8. Defæcation.

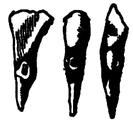
Prehension, the first step in digestion, is an office which that admirable instrument the hand, the lips, cheeks, incisor teeth, and tongue perform for man. The lips are highly sensitive and muscular, and are encircled by arteries. The maxillary divisions of the trifacial nerve endow them with great sensibility, and if divided, as done by *Sir C. Bell* on an ass, the guiding sensation is lost, and the animal will not take up food although presented to him. Many muscles surround the mouth and are supplied by the facial nerve, the buccinator being also supplied by the motor part of the trifacial. The tongue, an organ hereafter described, acts in many animals as a prehensile organ, and in the infant aids suction by being drawn back into the mouth like a piston. When the lips are tightly applied round the nipple a vacuum is produced by the expansion of the mouth, and the milk is forced from the breast by the atmospheric pressure upon it. Coryza interferes seriously with suckling.

Mucous Membrane is continuous with skin at the lips, and its structural anatomy may be here briefly described. It forms two great tracts or continuous sheets, the gastro pulmonary and the genito-urinary, and in addition the mammary tract in the female. The intestinal subdivision has two orifices, the others are cœcal. The membrane is termed simple when it has a plane surface, compound when folded inwards forming follicles, outwards forming villi or projections. Mucous membrane is everywhere composed of epithelium and basement layer.

Epithelium is of four kinds: 1. Flat, hexagonal or polyhedral cells, arranged in one or more layers. This is termed scaly or tesselated, and occurs in the mouth, pharynx, œsophagus, ureter, bladder urethra, and external female genitals. 2. Columnar, which is composed of rod-like cells narrower at the end where they are attached. It covers the intestinal villi, air passages, &c. 3. Ciliated, which is but the columnar variety, with the addition of cilia to its free extremities, as in nasal, bronchial, Fallopian surfaces, &c., and these in every case wave towards the outlets. Cilia are found on the tesselated arachnoid epithelium, but never on the next kind of epithelium. 4. The glandular, consisting of oval or globular cells, which in various secreting organs have the .power of choosing the materials of the special secretion from the blood. The second constituent of the mucous covering is the basement layer, a homogeneous lamina, with, occasionally, a slightly fibrous appearance. It corresponds underneath to areolar tissue, containing the nutrient vessels. A basement membrane is said to be wanting under the hepatic cells.

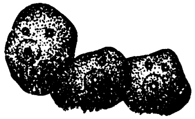


Tesselated (*Vagina*).



Columnar (*Intestines*).

Ciliated (*Trachea*).

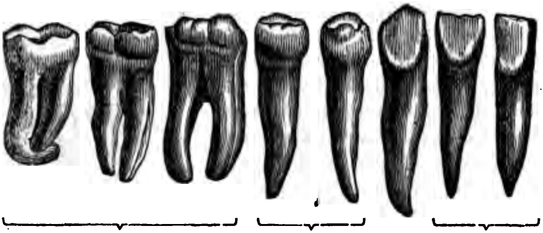


Glandular Epithelium,
(*Liver.*)

Mastication is aided by the cheeks, which roll the mass from side to side, mould it, and prevent it clogging outside the teeth; and the tongue, which besides its gustatory powers, canby it s exquisite mobility remove the food from any part of the mouth, and keep it always under the operation of the teeth.

The Teeth are arranged in two semi-parabolic curves, the upper and lower dental arches, of which the upper is the greater and includes the lower. This is of use in dividing the food; and by mutual attrition, the teeth, instead of being blunted, as they would be if they came just together, are bevelled on the posterior surface in the upper ones, and the anterior in the lower. In adult man there are 32 teeth, 16 in each jaw and 8 on each side, arranged from before backwards without any diastema, viz., 2 incisors for cutting, 1 canine for seizing, 2 premolar or bicuspid for tearing, and 3 molar for grinding the food, all contained within that "case of instruments," the mouth. These numbers are often expressed by *Owen's* dental formula:

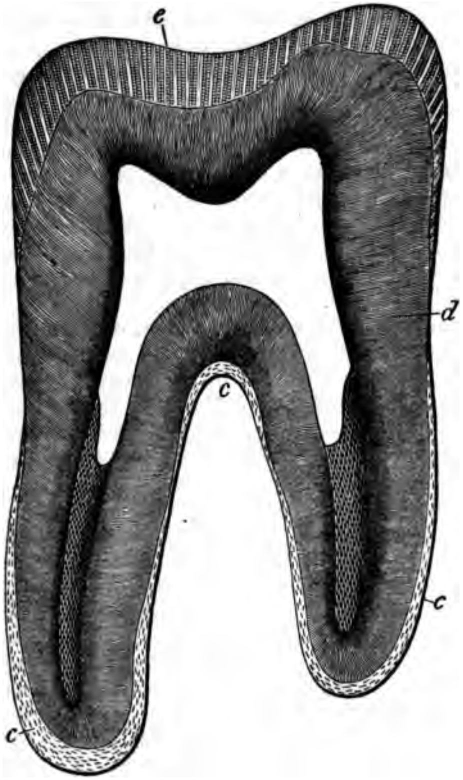
The Teeth.



$$i\,\frac{2-2}{2-2}\;c\,\frac{1-1}{1-1}\;p\,\frac{2-2}{2-2}\;m\,\frac{3-3}{3-3}=32$$

The same number exists in many animals, but many variations occur between the extremes of 1 in narwhal and 190 in dolphin. The close unbroken apposition of the teeth occurs in man only of living creatures, but has been found in the fossil anoplotherium, nesodon, and dichodon.

A tooth is divided into a crown, which projects above the gum, a vascular tissue grasping it at a slight groove termed the neck, and a root, consisting of one or more fangs, set into the alveoli of the jaw-bones. Enamel coats the crown; cement or crusta petrosa, the fang; and all the rest is composed of dentine or ivory. The body is hollowed out into the pulp-cavity, compared to an Haversian canal, and which contains a mass of looped nerves



Section of a Molar Tooth—c, cement; d, dentine; e, enamel.

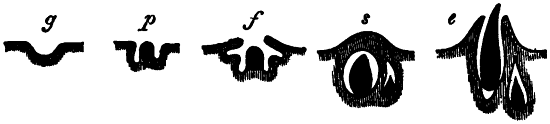
and blood-vessels transmitted through the tube in each fang. These parts are shown in the foregoing section.

Dentine (*d*) consists of fine tubes running from the pulp-cavity to the enamel or cement, in such direction as to oppose pressure applied to the crown or sides of the tooth. To confer some elasticity, they take two or three wavings, and small curves even to the extent of 200 in a line. They often branch in binary order, and dilate into lacunæ near the cement, thus forming the "granular layer" of *Tomes*. The dentine is marked by "counter-lines," which evidence stratification. The dental tubes are of very fine calibre, their wall being thick in proportion, admitting perhaps the thinnest part of the blood. Madder does not stain the tooth. Dentine contains about 72 per cent. of earthy salts. When teeth first appear, the crown is covered with a thin layer of cement, which soon wears away and exposes the enamel coated with a fine pellicle.

Enamel (*e*), having but 2 per cent. of organic matter, is the hardest substance in the body, and will strike fire with steel. It is arranged in pentagonal or hexagonal rods $\frac{1}{4500}$ in diameter, extending from the dentine to the surface of the crown, where they present an exquisitely smooth surface. Towards the dentine the rods are of unequal length, corresponding to that of dental tubes. High microscopic power shows transverse markings on the rods, connected probably with their development or nutrition, which may be also accomplished by the very slight spaces they leave between each other. The sensation produced by acid, when the teeth are said to be "on edge," is hard to account for, as no nerves probably exist in dental tubes, or between enamel-rods, but these may convey an impression to the nervous pulp.

The Cement (*c*) is a layer of bone crusting the fangs, and thus setting the tooth in its socket. *Albinus*' museum contains an upper molar with the fangs growing down, the crown in antrum. Up to 1839, dental tissue was described as a "dead part or product exhaled from the surface of a formative bulb," but their exquisite structure evidences organization, and being surprisingly varied in different animals, affords important zoological data.

The development of Teeth has been most carefully studied by *Prof. Goodsir.* They are appendages to the mucous, as hair and nails are to the cuticular surface, and no part of the true skeleton. In the fœtus, at six weeks, there forms along the edge of the hard palate "the primitive dental groove," at the bottom of which "papillæ" spring up and assume the shape of each future tooth. The groove is next partitioned into "follicles" by septa running between the inner and outer alveolar edge, and then the follicles become "saccules," by closing up round the papillæ. The papilla is analogous to that of hair, and is composed of granular matter, which becomes most highly vascular, and at last ossifies from the surface inwards, the dental tubes also forming. It corresponds only to the crown of the future tooth, and all below the neck subsequently ossifies, and thereby forces the crown to protrude through the gum. The enamel is developed in successive layers of particles, which explains the cross markings on the rods, and shows its analogy to cuticle, epithelium, or shells of some animals. It will be remembered that the stages have been successively—grooved, papillary, follicular, saccular; and now, finally, the "eruptive" stage begins.



Stages of Dental Development.

The following are the dates at which the papillæ of the twenty temporary or deciduous teeth—viz., 2 incisor, 1 canine, 2 molar, in each side of each jaw—appear: anterior molar, 7th week; canine, 8th; incisor, 9th; and posterior molar, 10th. Even at this early period the development of the permanent teeth is being provided for, by the mucous membrane being grooved into what *Goodsir* calls the "cavities of reserve." The deciduous teeth cut through the gum rather earlier in the lower than upper jaw, and about the following dates of infancy:

Central incisors	7th month.
Lateral incisors	before 10th.
Anterior molars	between 12th & 14th.
Canines	14th to 20th.
Posterior molars	18th to 36th.

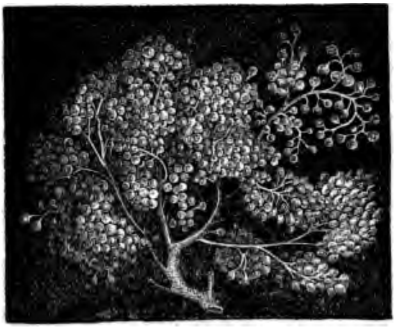
This completes the first dentition, an epoch often marked by convulsive and other reflex nervous diseases. The permanent teeth are being gradually ossified between birth and the third year, and come to lie at the inner edge of the milk-teeth, but much deeper. The fangs of these are absorbed and their crowns thrown off by the permanent teeth under them. The dates of this second dentition are:

Anterior molar	6½ years.
Central incisor	7th year.
Lateral incisor	8th year.
Anterior bicuspid	9th year.
Posterior bicuspid	10th year.
Canine	11th to 12th year.
Second molars	12th to 13th year.
Third molars, or "dentes sapientiæ"	from 17th to 19th year.

These dates, except the last, are very constant, affording proof of the age of children; and *Saunders* has proposed them as a test of their capability for factory work.

In man the movements of the lower jaw are most varied, combining, as in his teeth and food, the characters of both carnivora and herbivora. Depression is accomplished by the anterior belly of the digastric—which, in common with all masticating muscles, is supplied by the motor part of the trifacial nerve—and perhaps the mylohyoid, genio-hyoid, and genio-hyoglossus. Elevation, by the temporal, masseter, and internal pterygoid. Protrusion, by the anterior fibres of the temporal, the superficial part of the masseter, and the internal pterygoid. Retraction, by the posterior fibres of the temporal and the deep part of the masseter. Lateral motion, by the alternating action of the pterygoids, especially the external.

Insalivation occurs simultaneously with mastication, and thoroughly incorporates with the food the fluids from the parotid, submaxillary, sublingual, and the buccal glands, which are scattered over the cheeks, lips, palate, and back of pharynx. The structure of these is best studied by tracing the single excretory duct as it divides into most minute and numerous branches, ending in cœca and lined by epithelium. The cœca are surrounded by blood-vessels, and are grouped together by areolar tissue, which condenses on the surface into a capsule. Salivary glands are very simple in the fœtus and many lower vertebrata, among all of whom they exist—save fishes, the sea-water with them fulfilling some of the


Lobule of a Salivary Gland.

uses of saliva. Some fishes, however, as the carp, are said to ruminate, and a secretion like saliva is poured out by the pharynx. In the horse, cow, and some other animals, each side of the jaw and salivary glands are used alternately. Its flow is promoted by the motions of the jaw—probably, also, the pressure of the stylo-maxillary ligament alternately on the parotid and submaxillary, and remarkably by nervous influence. Every one knows that the sight, or even thought of food, will make "the teeth water."

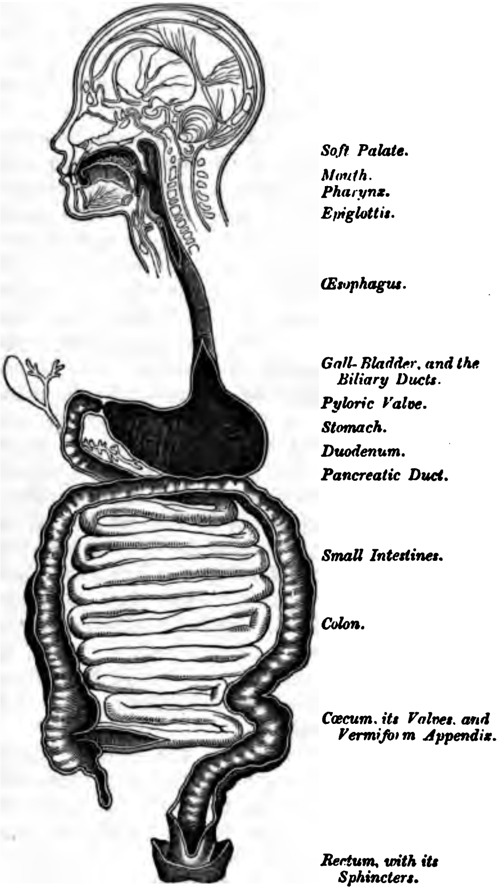
A good deal of saliva is poured out even after the food has been swallowed, the food in stomach exciting reflex action; so that, although "bolting" is injurious, the action of saliva takes place in stomach, the gastric juice not interfering with it, as once supposed. Lunatics and others fed through œsophageal tubes have digested normally. The daily amount is said to be 48 oz. by *Bidder* and *Schmidt.*

Saliva is a viscid fluid with a bluish opalescent tint, from epithelial particles, clearing as they subside, and often frothy, its mucus entangling air. Its specific gravity is 1007—9. It is alkaline in proportion, it is said, to the acidity of the gastric juice at the time, but the mucus of mouth during fasting gives it an acid reaction, which has also been remarked during inflammatory diseases. *Frerichs* found it contained,

Water	994·10
Salivin	1·41
Epithelium and mucus	2·13
Fat	0·07
Sulphocyanide of potassium	0·10
Fixed salts	2·19
	1,000·00

A trace of iron can be usually detected. The active principle salivin, or ptyalin, is a yellowish white, nearly solid matter—having alone the smell of saliva, soluble in ether, alcohol, and slightly so in water—and differing from albumen in being thrown down by acetate of lead and nitrate of silver, not by heat or nitric acid. It holds lime combined with it, and thus saliva, like lime-water, becomes turbid on exposure to air. There is none of it in the saliva of carnivora or sucking animals, as there is no starch in flesh or milk to be converted into sugar. Sulphocyanide of potassium is a salt peculiar to saliva, and recognisable by giving a blood-red tint with persalts of iron. It is absent during ptyalism, owing to dilution, and increased when sulphur is taken internally. The uses of saliva are mechanical or chemical. It reduces the food to a soft, slippery, and easily swallowed mass; it entangles air, and, by soaking food, lets the gastric juice more readily penetrate the bolus. But its main function is, by its ferment, salivin, to saccharize starch. If equal parts of saliva and decoction of starch, made with distilled water, and shown by *Trommer's* test to contain no sugar, be mixed, the latter loses its jelly-like appearance, produces no blue with iodine, but indicates sugar by its tests as fast as the experiment can be performed. Saliva also breaks the capsules of the starch grains. *Wright* states that symptoms like hydrophobia may be produced by injecting even pure saliva into blood-vessels of an animal. Salivary calculi and "tartar" consists of 20 per cent. of organic matter, and earthy phosphates, or, according to *Wright*, 80 per cent. of carbonate of lime, which salt, however, I found wholly absent in one instance.

Deglutition is performed by the mouth, tongue, palate, pharynx, and œsophagus, organs represented on the following page, and is aided by the thick lubricating mucus secreted by the tonsils—racemose glands between the arches of the palate. The act was divided by *Magendie* into three stages—1. The bolus is placed on the dorsum of the tongue, made hollow to receive it, and is then pressed into the pharynx by being squeezed up against the hard palate; the pharynx is



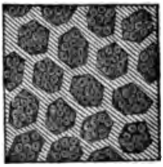
The Alimentary Canal.

now dilated by the larynx being moved forward and upwards, save that part behind the nares, which is closed by the palato-pharyngei in the posterior pillars of the soft palate, which is itself thrown up either by muscles or by mere pressure of food. 2. The bolus passes into pharynx, the glottis being closed by the lid-like epiglottis, which is forced down by the pressure of the tongue, the weight of food, and perhaps the aryteno-epiglottidean muscles; being very elastic, it springs up as soon as the food has passed; the middle and inferior constrictors now press the bolus into the œsophagus; (3) and is by it forced down into stomach. *Professor Corbett*, of Queen's College, Cork, has shown that fluids are swallowed in two streams by the sides of epiglottis and the folds which bind it to the arytenoid cartilages, the uvula serving to split the current.

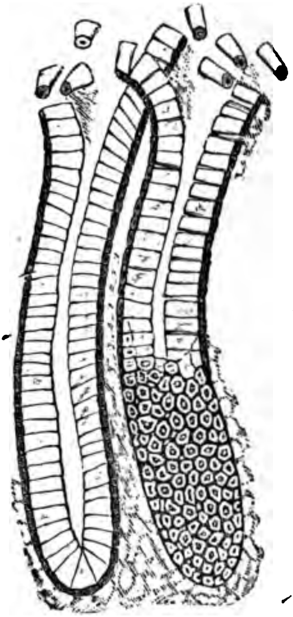
The œsophagus takes a very tortuous course, being in the median line, where it begins about the fifth cervical vertebra, to the left at the seventh, to the right at the third dorsal, below which it crosses the aorta in the posterior mediastinum, and opens into the stomach about one inch below, and to the left of the ziphoid cartilage, and opposite to the tenth dorsal vertebra. The muscular substance of the diaphragm, which it pierces, makes a kind of sphincter for it. The left pneumogastric in front, and the right behind, twine about it, and form the "plexus gulæ." The tube is covered by a lax, distensible areolar coat, and lined by a thick, lowly-organized mucous membrane, which has rather cuticle than epithelium, and a few mucous glands. Some cells of the yeast plant, sarcina, and vibriones, are often found upon it. There are two layers of muscular fibres. The outer longitudinal arises from the vertical ridge on the back of the cricoid cartilage, and is lost on the stomach; the inner, or circular, joins the oblique fibres of the stomach. Both layers are striped muscle above, but they become unstriped about half-way down.

The food does not drop by mere gravity into the stomach, but is worked down by the successive portions of the tube contracting. Matters are passed against gravity readily through it, as when the horse drinks, in vomiting; and men have exhibited the feat of swallowing while standing on their head. The tortuous course is not enough to prevent the food dropping down, for when the œsophagus is paralyzed or weakened before death, it falls into the stomach with a deep sound, like that of a stone in a well. Electricity produces continued contraction in the upper part, vermicular in the lower. The first stage of deglutition is voluntary, provided there is something to swallow, even saliva; but if this be exhausted we cannot perform the act. It will also occur when volition is suspended, a bolus being often administered to a comatose patient. The second stage is regarded as mixed or automatic; and the third is wholly involuntary. Division of both pneumogastrics causes the food to collect in the œsophagus.

The Stomach of man is a single pouch, narrowed, however, in the middle during digestion—the "hour-glass constriction" of *Sir E. Home*. Its coats are from without inwards (1) peritoneal, continued from diaphragm, liver, and spleen around the vessels; being an indistensible membrane, it is loosely attached by (2) the areolar layer to (3) the longitudinal muscular coat, which is best seen along the curvatures, especially the lesser. 4. Circular fibres are developed at the cardiac orifice where they help the diaphragm in making a sphincter, and at the pylorus where they make a circular valve with an aperture compared to iris and pupil. This valve gradually opens as digestion progresses. 5. Oblique muscular fibres abound of the great bulging end. Condensed areolar tissue forms a 6th coat, which *Sir C. Bell* named "nervous" from its colour and plentiful supply of nerves, from the pneumogastrics, left phrenic, and solar plexus. In it also the arteries from the gastric, hepatic, and splenic, and the veins running to the porta, ramify. The 7th and last plane is the mucous membrane. This surface is thick and velvety, pale and plicated during fasting, extremely vascular and distended during digestion. It is depressed into pits or "alveoli" of an irregularly square form, about $\frac{1}{200}$ in diameter, and of about $\frac{1}{8}$ of the depth of the membrane. These pits were first accurately described by *Dr. Sprott Boyd*, from whose paper the annexed cut is copied. The walls of these alveoli contain abundant capillaries, and from the bottom of them lead off five or six tubes dipping into the remaining thickness of the coat. These stomach-tubes (sieve-like follicles of *Lieberkuhn*) differ at the cardia and the pylorus. At the cardia they branch into two or three cœca, and are lined by round epithelial gland cells filled with granules. These are the true "peptic glands," alone secreting acid or pepsin, according to *Kölliker*. The tubes near the pylorus do not branch, are lined by very large columnar epithelium, and secrete mucus. The stomach-tubes of the pig are here represented. The motions of the stomach may be seen when food or



Alveoli and Stomach-tubes.



Stomach-tubes from Pig.

other stimulus is introduced, and the direction of them them is best indicated by a rod inserted through a gastric fistula. The stomach contracts upon the food, which does not escape as the orifices are closed, the contraction being most marked towards the pylorus, or at the centre, producing the hour-glass shape, which can be produced by electric stimulus in animals, or criminals who have been dissected just after execution. This contraction is about four inches from the pylorus, and prevents the food passing through too soon. That it divides the organ into a cardiac portion for maceration and a pyloric portion for digestion is disproved by the true peptic glands being more numerous towards the cardiac orifice.

The mass of food passes from the cardiac orifice to the bulging end, then along the greater curvature to the pylorus, aud hence back to the cardia along the lesser curvature, the revolution occurring in from one to three minutes. In carnivora the motion is from side to side. That no energetic trituration occurs in the stomach, *Spallanzani* proved by placing food in perforated metal tubes out of which it was digested. Stimulation of the mucous surface, as by food, renders it red and turgid as a foreign body reddens conjunctiva, and gastric juice oozes plentifully out, none being secreted during fasting. Much slimy mucus is poured out by the stomach, but is at once checked by the section of the vagi, according to *Sir B. Brodie*. *Bernard* states that irritation of the pneumogastric nerves promotes, of the sympathetic checks the flow of gastric juice. The *Abbè Spallanzani* obtained gastric juice by making animals swallow sponges with a string attached for withdrawing it—an experiment I have seen a zealous professional friend perform on himself. *Dr. Stevens* experimented on a hussar, who had acquired the power of swallowing so many stones that they would rattle on striking the epigastrium; he found that living leeches and earthworms were digested.

Dr. Gosse, who could vomit at will, made also some valuable observations.

We owe, however, nearly all our knowledge on the subject to the following cases: 1. Alexis St. Martin, a Canadian boatman, in whom there existed a large gastric fistula, the result of a gun-shot wound. *Dr. Beaumont* most ably investigated this case, obtained gastric juice, and observed the action of food on the stomach, and of the stomach on food. 2. Catherine Kütt, aged 35 years, who had a gastric fistula opening between ninth and tenth left costal cartilages, from which *Schmidt* obtained 31 ℔ of gastric juice daily, of which 100 parts were required to dissolve 2½ parts of albumen. *Lehmann* calculated the daily amount at from 60 to 80 ozs., as we ingest daily 3 or 4 ozs. of pure albumen, and finding that 5 parts are dissolved by 100 parts of that fluid. The amount of gastric juice is proportional to the wants of the system, not to the quantity of food taken—a most important principle in dietetics, as any surplus must remain undigested, and in many feverish states none is secreted if food be taken. It is a colourless, slightly viscid fluid, with a sour smell and intensely acid reaction, specific gravity of 1·0023, and the following composition:

	Catherine Kutt.	Sheep.	Dog.
Water	994·404	986·147	971·171
Pepsin	3·195	4·202	17·507
Hydrochloric acid...	0·200	1·557	2·703
Chlorides	2·076	6·001	5·881
Phosphates	0·125	2·090	2·738

The pepsin and acid may be regarded as a conjugated acid—the pepso-hydrochloric. There is probably much more acid, as in these analyses saliva and other alkaline matters may have neutralised a large amount. That the acid is hydrochloric is probable from the necessity there exists for the use of common salt, which would afford this acid for the gastric juice and soda for the bile; it has been surmised that the pepsin may separate them. The fact that hydrochloric acid is the most highly diffusible of substances may have some connexion with its presence in the gastric juice. The presence of lactic acid was first stated in 1823 by our illustrious countryman, the late *Dr. Graves*, and since by *Berzelius*, and was obtained in 1856 from Alexis St. Martin, who has again submitted to experiment. *Blondlot* asserts that biphosphate of lime, and no free acid, exists—a view disproved by the fact that gastric juice, if heated with zinc, evolves hydrogen, whereas a solution of acid phospate will not. No mixture, however, of acids will digest alimentary matters without the aid of great and prolonged heat; but this necessity for high temperature is removed by the active principle, pepsin. This is contained in the dried mucous membrane of the fourth stomach of the calf, which is known as rennet, and was isolated therefrom by *Wasmann*. It acts as a ferment, being probably a protein body undergoing decay, and produces some catalytic effect on albuminous food, putrefaction being checked by the presence of the acid, for an artificial digesting fluid made from pepsin, without acid, putrifies.

Gastric juice acts mainly on the albuminoids, changing them into "peptone," which is identical, though derived from meat, cheese, albumen, &c. This substance, alluded to by *Prout* as "incipient albumen," is not coagulated by heat or nitric acid, and is much more soluble, and thus more easily absorbed through coats of vessels. Peptone does not give the red colour by *Millon's* test, but is thrown down by alcohol and bichloride of mercury, and has the effect of interfering with such chemical reactions, as the blue colour of starch with iodine, the reduction of oxide of copper by sugar, as in *Trommer's* test, &c. No great chemical change occurs in the production of peptone, as no gas is evolved, and the amount of sulphur is the same as in albuminoids. It is probable that peptone is but a crystalloid form of albumen, that substance, by a change from its colloid condition, being readily diffusible through the coats of the stomach and the superimposed layer of mucus. Milk introduced into stomach is at once curdled, its casein being then converted into peptone; if too much, however, be forced upon an infant, it passes away in the stools. The peptone is taken up by the gastric veins as rapidly as formed, and being circulated through liver by the porta, may excite that organ to pour out bile for the next digestive step. The gastric juice is never free in the stomach in large quantity, but is being absorbed and re-secreted, which accounts in some degree for the stomach itself not being digested, but the rapid renewal of epithelium is also protective. The alkaline reaction of the circulating blood neutralizes also the acid of the gastric juice, according to *Pavy*, who, however, has shown that living frog's leg, if retained in the stomach of a dog, will be digested almost as rapidly as if dead. The stomach of man has, however, been found digested or softened, as described by *Hunter*, and the fact has medico-legal importance, as it may be mistaken for the effect of corrosive poisons or chronic ulcer. With regard to the action of the stomach on other substances, fat is only melted, sugar and gelatin probably absorbed, being the only calorific food the stomach acts on, while starch, cellulose, &c., are unaffected. Iron is converted into its oxide and peroxide.

Absorption from the stomach will be dwelt on in the next chapter; but it may be here stated that some substances are either not absorbed or are much changed in absorption. Thus, if emulsin be put in the stomach of a dog, and amygdalin in the veins, no formation of hydrocyanic acid or injury to the animal results; but, on the contrary, if the emulsin be introduced into veins and amygdalin into the stomach, rapid poisoning occurs. Gentle exercise and mental quiet seem to promote digestion; strong alcohol and metallic salts check it by throwing down the albuminoids. Bile has a most remarkable power in arresting the process, hence the connexion between misplaced bile and "indigestion." As we have seen, foods are not always of value according to the amount of nutritive matter they contain, but also according to their digestibility or rapidity of assimilation.

The time occupied by the digestion of an ordinary meal was said by *Beaumont* to range between 2¾ to 4 hours, fish and veal being the extremes. More accurate knowledge may be obtained by the plan invented by *Blondlot* of making fistula in animals, and disease has produced an admirable subject for experiment, as observed by *Busch*, who met with a case of jejunal fistula. His results are shown in the following table:

	Appeared in Minutes.	Weight changed from 1 to	Proportion of solids changed from 1 to
Boiled eggs........	30	2·73	0·76
Flesh...............	26	1·73	0·35
Cabbage............	17	0·91	0·58
Potatoes..	15	0·7	0·53
Parsneps...........	12	1·2	0·49

Much fat, as in nuts, mushrooms, and many meats, is indigestible; and thus the flesh of wild animals, as venison, containing least of it, are most digestible. Some matters, as vegetable husks and skins, and yellow elastic tissue, pass quite unaltered, while bones are acted on, their salts being dissolved by the acid.

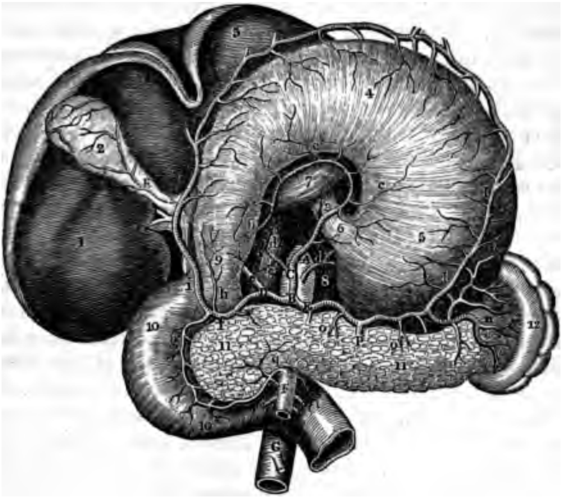
Besides rumination, or voluntary return of the food to the mouth, which characterizes a great class of animals, and has been seen in man, the food may leave the stomach by vomiting, or gases may be evacuated in vast quantity by eructation. The mucous surface seems to secrete gas in some cases, especially in old persons of weak digestion, or fermentation may evolve it, if it occurs instead of mere digestive catalysis. Gases escape most readily when the body is erect, as they rise to the cardiac orifice. Fresh powdered charcoal, which has great absorbent power for gases, I have found gives much relief in such cases.

The Act of Vomiting is accomplished by the stomach contracting while the cardiac orifice is open, the pyloric closed, so that it will not let fluid pass from the stomach, but will from duodenum, as seen in hernial vomiting. The abdominal muscles, also, press the stomach against the diaphragm, which is fixed and depressed by a previous inspiration. The glottis is closed during vomiting, so as to prevent expiration, and a loud, sudden inspiration often succeeds the act. *Magendie* believed the stomach was passive in vomiting, as he could produce it in a dog, whose stomach was removed and a pig's bladder substituted, by injecting tartar emetic into the veins. However, *L'Epione* saw the organ contract vigorously in a man whose abdominal walls had been accidentally ripped open, and the same has been demonstrated by vivisection on animals. The muscular action by which the contents of the stomach and intestines are forced in a reverse direction, as in strangulated hernia, is usually considered antiperistalic, or the opposite of the normal course. *Dr. Brinton* regards this explanation unnecessary, as, if there be an obstruction, the ordinary pressure will force the fluid back through the centre of the tube, as if one used a perforated piston. If, however, the œsophagus be removed from an animal into whose veins tartar emetic has been injected, the vermicular action is found to be towards the mouth. All excitants to vomiting act on the nervous centres or periphery—thus, the sight or smell of a disgusting object, irritation of the medulla oblongata, mechanical irritants in the stomach, as mustard or salt, emetics absorbed or injected, and tickling the fauces, are either direct or reflex provocants of the act.

Stomachic digestion, we have seen, is mainly that of plastic food, and the resulting fluid, the chyme, chiefly consists of fat, perhaps sugar, any starch unchanged by saliva, and indigestible residue.

Intestinal Digestion, which is chiefly of calorific food, begins in the duodenum, two fluids, bile and pancreatic juice, usually through the same opening, being poured on the food. The liver and bile will be found described in another chapter, but we shall here mention its uses in digestion, which are much less important than formerly supposed. We have seen that it arrests chemical change in the stomach, and, in the same way, it checks decomposition of the albuminoids, and thus prevents greater fœtor in the fæces. It may neutralize, by its alkali (which, however, is very scanty) the acidity of the chyme, and is thought to stimulate the intestines, being often termed "nature's purge." Fœtor and constipation are certainly symptoms of jaundice. Its main use is to promote osmose by rendering the walls of the vessels more permeable to fat, for if a capillary tube be wetted with bile, it will be found that oil will rise six or eight times higher in it than if dry or wetted with water. The detergent and saponifiable properties of gall are well known to scourers. Although it has then no direct digestive action it is not merely excrementitious, as, if excluded from the intestines of dogs, and yet perfectly excreted by a fistula, they die emaciated, no fat being absorbed. All the constituents of the bile are not found in the fæces, as their amount of sulphur is not increased, but, like gastric juice, it is being secreted, absorbed, and re-secreted by a kind of circulation.

The Pancreas is a flat, pinkish-white gland placed across the second lumbar vertebra, about 7 inches long, 3 broad, 1 or 2 thick, and about 3 oz. in weight. It resembles the salivary glands so much as to be named "the abdominal salivary gland," as it is lobulated, incapsulated merely by areolar tissue, and has no special or single artery. It differs in being single, in having its duct all through it, and in its secretion. Its structure, relations, and abundant supply of blood, as well as that of some other digestive viscera, is shown in the annexed figure. Mercury injected shows that the gland is composed of lobules, which are cœcal terminations of the minute branches of the common duct connected by areolar tissue, and all lined by the peculiar secreting cell. The duct, which was discovered by *Wirsungius*, passes from tail to head, one-third from the posterior surface, receiving its tributaries at right angles, like the legs of a centipede, and, joining the bile duct, opens into the lower part of the vertical division of the duode-



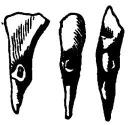
The solid organs exposed by turning upwards the stomach. 1. *Right Lobe of Liver.* 2. *Gall Bladder.* 3. *Left Lobe of Liver.* 4, 5. *Stomach.* 6. *Œsophagus and Cardiac Orifice.* 7. *Spigelian Lobe of Liver.* 8, 8. *Cruræ.* 9. *Pyloric Orifice.* 10, 10. *Superior transverse and inferior transverse portions of Duodenum.* 11, 11, 11. *Head, body, and tail of Pancreas.*

num. The gland exists in all vertebrates, save perhaps some fishes—the shark, ray, and some osseous fishes having it, and the pyloric appendages of others being analogous.

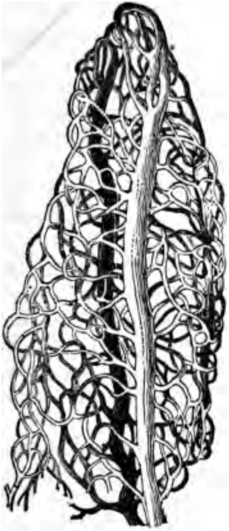
The secretion may be obtained by rapidly inserting a tube into the duct of a dog after it has been fully fed. It is a colourless, viscid, or syrupy fluid, frothing on being shaken; has a sp. gr. of 1·010, and is always alkaline. Every drop of it is changed into a solid mass by heat, nitric acid, alcohol, and some salts, becoming fluid again by adding an alkali. If the mass, solidified by heat or alcohol, be dried, it will dissolve in water, thus differing from albumen—which, however, *Tiedemann* and *Gmelin* said was present to the amount of 4 per cent. This animal matter is termed pancreatin, or phymatin. It rapidly putrifies, but does not ferment sugar nor change urea into carbonate of ammonia. On mixing pancreatic juice with oil, fat, or butter, and agitating for some minutes, a perfect emulsion, like milk, is obtained. The odour of butyric acid is evolved if butter be used, which shows that some separation of fatty acids and the base glycerin occurs. If the duct be tied, the fat is passed unabsorbed, and the chyle is found colourless. This explains those cases of "diarrhœa adiposa" reported by *Dr. Bright*, and produced by diseased pancreas. The same action is shown in the rabbit, where the pancreatic opens 17 or 18 inches lower than the bile duct; if the animal be fed on fatty food, the upper lacteals will contain a colourless, the lower a white chyle. This emulsifying power is owing to its albuminoid principle enveloping each particle of fat with a cell-wall, so that they are prevented from running together, and being thus kept in a finely divided state, are more easily taken up by the lacteals. No other animal fluid can emulsify, save, perhaps, that of *Brunner's* duodenal glands. It is thought, in common with saliva and many solid tissues, as that of the gland itself, to saccharize starch. That the pancreatic juice, and not the saliva, is the agent for the conversion of starch into sugar is an opinion advocated by *Pavy*, who says that the saliva of dogs has no saccharizing power: however this may not be true of vegetable-feeders. *Corvisart*, *Brinton*, and *Harley* believe pancreatic juice may produce peptone from any albuminous matter which has escaped the action of gastric juice. This is probable if it become acid—for the main difference between these digestive fluids is their reaction; if acid, acting on nitrogenized matter; if alkaline, on unnitrogenized.

The Intestines measure about 25 feet, from the pylorus to the anus, the small intestine being about 20 feet, and the great intestine, from the cœcum to the anus, about 5. From this tube there is always a diverticulum, the vermiform appendix very large in rodents, but of unknown use. Other diverticula occasionally exist, and have been admirably described by *Prof. Struthers*. The coats of the intestines are arranged in four planes:—1. Serous, which is almost complete in the jejunum and the ileum, partial in the duodenum and the great intestine, and absent for the last 3 or 4 inches of the rectum. It is indistensible, so a loose areolar layer ties it to (2) the muscular coat. This consists of two layers—a longitudinal, best marked along the attachment of mesentery, and a circular, far more abundant, surrounding, in complete circles, the (3) fibrous coat, in which vessels and nerves break up into very minute and numerous branches, the latter presenting frequent ganglioform dilatations. 4. The mucous coat, which is of the compound variety, bending inwards to form the follicles, or outwards, for about the same distance over the villi.

The Follicles (with which *Lieberkuhn's* name is often, without reason, connected) are cœcal tubes dipping through the whole depth of the mucous membrane, lined and almost blocked up by columnar epithelium, which produces the intestinal juice. They multiply the mucous surface enormously, but decrease in number and depth gradually from the jejunum, as do also the valvulæ conniventes. These, which are so called because they flap or wink like the eye-lids, are permanent folds of the fibrous coat, doubly covered by mucous membrane, whose surface they thus much increase. They pass somewhat spirally round the gut for about three-fourths of its calibre, and project into its cavity a quarter or half an inch.

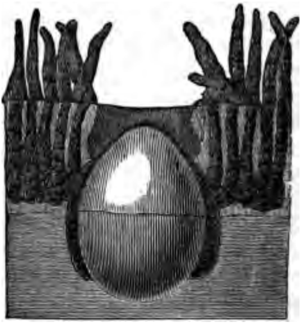

Epithelial Cells from jejunum.

The Villi are like everted follicles, giving the membrane its velvety character, and increasing gradually from the duodenum to the jejunum, where 10,000 have been counted on the square inch. Thence they gradually get fewer, and cease on the surface of the cœcal valves towards the ileum. They are slightly tapering, and about $\frac{1}{50}$ long. There is an artery on one side, a vein on the other, joined by a capillary flexus of astonishing minuteness surrounding a branching lactael.—These vessels are supported by a fine areolar tissue filled with granules, which gradually develop into cells towards the free end of the villus. When active, a villus becomes opaque and turgid with blood, and under prolonged fasting, shrivels up. *Kölliker* has discovered in them a layer of muscular tissue continued from the intestine. It may force onward the chyle. In the duodenum alone are *Brunner's* glands, which are racemose, like salivary or pancreatic glands,


The Artery, Vein, and Capillaries of a Villus.

the latter of which they closely resemble in function and structure, save that they are spread out under the mucous membrane of the upper part, and the concavity of the gut especially.

The Gland Cells.—Throughout the whole canal are found glands, or rather shut cells, of a shape aptly compared to an India-rubber bottle, with the broader end set in the areolar coat. They appear the size of a mustard seed when viewed by holding the gut up to a strong light. Some are scattered singly (glandulæ solitariæ), some grouped (glandulæ agminatæ), into about 18 or 20 oval patches, 2 or 3 inches long, chiefly found in the ileum. The latter are usually named after *Peyer*, who accurately described them; but they were previously mentioned by *Grew* before the Royal Society of London. *Allen Thompson* describes in many of them a muscular pupil-like opening, as if they had burst and discharged their contents. They often lie in the angle made by the dividing of a vessel which forms a plexus about them, and sends loops into them—as in the spleen cells represented further on, which they seem to most closely resemble. Such cells may be found also in the liver. They were formerly supposed to produce the intestinal juice, but they are much more probably absorbent organs, in which chyle-cells or molecular base may be elaborated, such being much more abundant in lacteals coming from near the Peyerian patches. They are also said to confer the peculiar odour on the fæces; and



Peyerian Gland half set in submucous tissue, surrounded by two of the follicles which open into the depression at its free end. Villi and follicles are seen around it.

it may be that decomposing matters and animal poisons are eliminated by them.

Schmidt guesses that about 10 ounces of intestinal juice is poured out. We have no information as to its composition, but is supposed to act on starch, which it saccharizes, either if mixed with it, or if confined in a loop of intestine. It acts on fat and albuminoids, as they are certainly assimilated if introduced, as in nutritive enemata. The bowels are constantly undergoing a vermicular action, which can be readily seen by opening the abdomen of a rabbit lately fed. The animal should be rendered insensible by a blow over the medulla oblongata. The contractions proceed downwards, the gut being distended by food below the constriction, and also above as relaxation succeeds. In man, wounds and great emaciation of the parietes have rendered them visible. Electricity much increases these motions, which are ordinarily excited by the contact of food acting on the sympathetic, and perhaps by the distension of the muscular fibres by gas. The intestinal gases vary, as shown by the following table, in various parts of the digestive canal:

	Stomach.	Small Intestine.	Colon.	Expelled by Anus.
Nitrogen	71·45	20·08	51·03	1·40
Oxygen	11·00	—	—	—
Carbonic acid	14·00	24·39	43·50	44·5
Hydrogen	3·55	55·53	—	25·8
Carburetted hydrogen.	—	—	5·47	15·5
Sulphuretted hydrogen.	—	—	—	1·0

This last gas is often eructated in oxaluria. The nervous system seems to influence the secretion of gas. They often distend the intestines in hysteria and fevers (meteorism). In the cœcum, or first portion of the great intestine, an acid juice is poured out, but how far it may effect any digestive action, is unknown. After this, the alimentary mass is destitute of any nutritive material, and all future provisions are for its expulsion. As the fæces pass down the great intestine, they become more solid, are moulded to the shape of the gut, and, lastly, remain in the rectum for defæcation.

In the lower Bowel the fæces do not bear on the anus constantly, but are supported by 3 valves, described first by *Houston*. One is found at the beginning of the gut, a second about the middle of it, and a third lies about 3 inches from the anus. They act like "shelves to pack the fæces on," and when the bowel is empty, may be so close as to render the introduction of a bougie difficult.

The external and internal sphincters keep the lower end of the rectum closed till they are overcome by the detrusive efforts of the intestine, assisted by the diaphragm, abdominal muscles, and other muscles which act in expiration. The sphincters are kept closed by tonicity and the absence of any direct antagonistic, rather than by constant muscular action, which should tire. The rectum pours out thick mucus, which lubricates, and so facilitates the expulsion of the fæces. The desire for evacuation of the contents of the gut is usually excited by its distension; but greater bulk, or irritating qualities of the mass, or an over-sensitive state of the mucous membrane, may render the act a reflex one.

Habit has much to do with the frequency of defæcation, as shown by the two instances related by *Heberden* — one individual having a motion habitually but once a-month, and another who had one twelve times daily for thirty years. A distinguished surgeon of this city has informed me of a remarkable instance of the influence of habit over defæcation: a clerk in a public office went to stool on every week-day at a certain hour at his place of business, but was never able to free his bowel on Sunday. A healthy man passes daily about five or six ounces of solid fæces, there being much more on a vegetable than on an animal diet. The remains of the food which are found in the fæces are in a highly oxodized condition, and *Liebig* has given the characters and odours of fæces to food by fully oxidizing it with liquor potassæ. Their smell, which is not very dissimilar from that of blood and skin, and their colour are mainly derived from the bile. The microscope discovers disintegrated muscular fibres, cartilage cells, elastic tissue, fat cells, spiral vessels of vegetables, mucus, and the ammonio-magnesian phosphate, which salt was once believed to occur only in cases of typhus fever. Only ⅛ of the bile the liver secretes is discharged by this channel. On analysis, *Berzelius* found solid excrement to consist of

Water	75·3
Bile	0·9
Albumen	0·9
Peculiar extractive	2·7
Salts	1·2
Insoluble residue of food	7·0
Mucus, fat, bile-resin, and peculiar animal matter	14·0

Much of the matter introduced into the alimentary canal is removed by other channels, as shown by *Barral*, who performed experiments on himself to determine the daily amount of ingesta and egesta. His results are given in ounces:

INGESTA.

	Solid Food.	Liquid.	Oxygen.
July	24·4	59·7	27·42
December	39·2	57·9	37·44

EGESTA.

	Water by Skin and Lungs.	Carbonic Acid.	Urine.	Fæces.	Nasal Secretion.
July	40·27	31·34	36·14	2·66	1·19
Dec.	45·43	43·32	39·97	5·00	1·75

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. What divisions of food have been adopted?
2. In what regions are saccharine and fatty foods, respectively, adopted by man?
3. Arrange a list of ordinary foods in the order of their nutritive qualities.
4. State some of the effects of cooking on flesh, and the best methods of extracting soups.
5. Describe the varieties of bread and the relative nutritive value of each.
6. What ideas have been entertained as to the proximate cause of hunger?
7. Enumerate the stages of digestion.
8. Describe the structures which form the crown of a tooth.
9. State the composition and uses of saliva.
10. Enumerate the coats of the stomach and describe the most internal.
11. What uses have been assigned to the pancreatic juice?
12. How are the gland cells of the small intestines arranged, and what ideas are entertained as to their purpose?

SENIOR.

1. Cite the arguments for and against the statement that alcohol is respiratory food.
2. State some of the advantages of retaining the blood in flesh-meat.
3. Adduce some instances showing the need of a mixed dietary.
4. By what physiological principles should the times of meals be regulated for adults and children?
5. State the symptoms, post mortem appearances, and time of death in case of starvation.
6. What proofs can you offer that thirst is not merely a local sensation?
7. Describe mucous membrane and state where each variety of epithelium occurs.
8. Detail *Goodsir's* observations on the development of teeth.
9. Describe the modes in which solids and fluids are swallowed.
10. From what cases have physiologists obtained most information on the subject of stomachic digestion? detail some of the observations.
11. Describe the structure and functions of the villi.
12. Give the composition of the gaseous and solid alimentary excreta?

cal processes, as secretion, nutrition, respiration, as well as the introduction of poisons, the action of purgatives, &c., depend on the principles we have been endeavouring to explain.

Absorption may be either venous or lymphatic, and will be most conveniently described under the heads of Alimentary and Lymphatic. Ulcerative, progressive, and interstitial absorption, as described by *Hunter*, are morbid processes, and will be hereafter alluded to. We have already seen that most of the nutritive matters of the food, when converted into the soluble form of peptone, are removed from the cavity of the stomach by the veins which so abundantly ramify in its mucous membrane. The rapidity of this removal varies with a replete or an empty state of the blood vessels and stomach. *Erichsen* found that it took 39 minutes for ferro-cyanide of potassium to appear in the urine, if the stomach into which the salt was introduced was full of food; whereas it appeared in the almost incredible space of 1 minute if the stomach was empty. He performed his well-known experiments on an individual whose bladder opened on the anterior abdominal wall (ectropia vesicæ), as he could examine the urine the moment it trickled from the ureters. As intimately connected with stomachic absorption, we shall briefly allude to the actions of medicines, which have been admirably investigated by *Headland*, whose results are shown in the following propositions:

1. "That the great majority of medicines must obtain entry into the blood or internal fluids of the body before their action can be manifested." A vascular connexion is therefore necessary for the passage of the medicine, and will suffice when nerves and other tissues are severed. The enormous rapidity of the action of some poisons will be understood, when it is remembered that *Blake* found chemical substances could be transferred through the circulation of a dog in 9 seconds.

2. "That the great majority of medicines are capa-

ble of solution in the gastric or intestinal secretions, and pass without material change, by a process of absorption, through the coats of the stomach and intestines, to enter the capillaries of the portal system of veins." Saline purgatives would form an exception, if, as *Poisseuille* stated, they acted by making the serum of the blood ooze out as the saline solution of higher specific gravity passed along. *Headland* has opposed this theory with many ingenious arguments and experiments, and shown that dense solutions will pass through a membrane to a lighter one (as we have stated with regard to water and alcohol), and that solutions of low specific gravity will produce purging.

3. "That those medicines which are completely insoluble in water, and in the gastric and intestinal juices, cannot gain entrance into the circulation." *Œsterlen*, however, states that finely powdered charcoal, if given to rabbits, will pass through, and can be found by the microscope in the blood of the porta. No such results have been obtained after carefully conducted experiments. The structureless basement layer of mucous membrane would seem to be impermeable to solids, however minutely pulverized.

4. "That some few remedial agents act locally on the mucous surface, either before absorption or without being absorbed at all," as irritant emetics or cathartics, and superficial stimulants, sedatives, or astringents.

5. "That the medicine when in the blood must permeate the mass of the circulation, so far as may be required to reach the parts on which it tends to act."

6. "That while in the blood the medicine may undergo change, which in some cases may, in others may not, affect its influence"—such as combination, as when an alkali unites with acid of the gastric or intestinal juices; reconstruction, as when tannic acid changes into gallic;

benzoic into hippuric acid; or decomposition, as when the salts of vegetable acids are decomposed, rendering the urine alkaline, as explained by *Wöhler*.

Dr. Headland classifies and indicates the action of the most important medicines under the following heads:

I. **Hæmatics.** They act while in the blood, which they influence permanently—either by restoring a deficient material (restoratives, as iron in chlorosis) or by counteracting a morbid material or process (catalytics, as mercury in syphilis).

II. **Neurotics**, which act on the nervous system, either exalting its force (stimulants, as ammonia), exciting its powers, to be followed by their depression (narcotics, as opium), or depressing them directly (sedatives, as hydrocyanic acid).

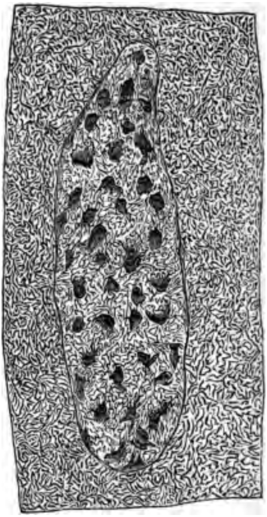
III. **Astringents**, which act by causing contraction of the tisuses composed of albuminoids, especially muscular fibre, as tannic acid.

IV. **Eliminatives**, which act by exciting to increased secretion the glands whereby they pass away. Such are sialogogues, which increase saliva, as mercury, iodine, betel; expectorants, which increase bronchial mucus, as tartar emetic, hippo, squills; cathartics, which increase intestinal fluids, as jalap, elaterium, sulphate of magnesia; cholagogues, which increase bile, as mercury, manganese, taraxacum; diaphoretics, which increase perspiration, as antimony, nitre, guaiacum; and, lastly, diuretics, which increase urine, as water, salines, cantharides.

That many substances have their poisonous action destroyed by the action of the stomach is shown by many animals feeding on wourali, so fatal if inserted into a vein. The poison of the viper does not injure, it is said, snakes, tortoises, leeches, &c.

The peptone and sugar being removed from the food, the acidity of which promotes osmose towards the alkaline blood or chyle, there still remains to be absorbed the fat, which is gradually taken up by the villi along the small intestine.

The Lacteals, the vessels the villi contain, were discovered, in 1622, by *Asselli*, in the mesentery of a dog which he had fed on fatty food. He thought they ended in the vena portæ. They begin by a branching tube in the villi, which may be compared to the spongioles of the root of a plant. The finely divided or emulsified fat is taken up by the epithelial cells, and transferred to the lacteal within the villus, as *Weber* believes; whereas *Goodsir* thought the epithelium was shed before absorption, and it was once believed that the lacteals began by open mouths. That fat is chosen was said to indicate a selective power, but it is merely because fat has passed through before, and is thus more readily absorbed than other fluids. We have before mentioned that *Peyer's* glands seem connected with nutritive absorption. A patch of them is here represented, and they are described at page 89. The chyle flows through the lacteals at very inconstant rates, but *Cruikshank* stated its velocity as 4 inches per second. It passes next through the mesenteric glands, where more fibrin and cells are developed, and is poured by 5 or 6 trunks into the thoracic duct. *Pecquet*, by vivisection—for he condemned dissection as a "mute and frigid science"—first demonstrated this duct. It courses through the posterior mediastinum and opens into the left subclavian vein, re-



A Peyerian patch.

ceiving all the lymphatics, save those of the right side of the head, and the neck, and the upper extremity, which open by the right lymphatic duct of *Steno* into the right subclavian vein. What is termed the anterior thoracic duct is but a lymphatic from the liver passing behind the sternum. Through the lacteal system, while fasting, ordinary lymph is passing, from which chyle differs by the amount of fat; but the fibrin and other materials are not increased by the digestion of food.

Many other matters are absorbed rather by veins than lacteals, such as salts, poisonous substances, &c.—a view so fully argued by *Hunter* and *Monro*. *Panizza* proved it by placing hydrocyanic acid in a fold of gut in a living horse, after having separated the vein leading from it. As long as he kept the vein compressed, no effect occurred; but when the pressure was removed, the animal was poisoned, and some of the blood extracted from the vein contained the poison. Similar experiments were performed on the leg, all but the vein being divided, and lest it might be the absorbents in the coats of the vein which carried up the acid, a tube was placed between two divided portions of it. *Waller* found the poison was much more rapidly absorbed if the sciatic nerve were divided. The chyle is moved upwards, in opposition to gravitation, by the vis a tergo which succeeding portions acquire from the muscularity of the villi, the lacteals, and the thoracic duct, and the pressure of the aorta against the latter, but mainly by the rapid flow of blood in the large vessels into which it is poured. *Venturi* proved that the flow through a capillary tube is much promoted if it opens into a transverse tube in which fluid is passing, a principle applied to drainage.

The Chyle poured into the blood gradually disappears from that fluid by replacing materials which have been exhausted; but if dogs are bled after a full, fatty meal, their serum is found turbid from fatty chyle. In cases of apoplexy occurring after a meal, chylous blood has often been found. Chyle, under a microscope, is seen to contain fat cells, and cells similar to the white ones of blood and lymph, and a "molecular base," as *Gulliver* termed it, whose particles are but $\frac{1}{30000}$. That the colour of chyle depends on the fat of food, is shown by its being quite transparent if animals are fed on jelly. *Bidder* and *Schmidt* calculate that 6℔ is daily poured into circulation. The most reliable analysis is that of *Dr. G. O. Rees*, who obtained chyle from the thoracic duct of a criminal who had taken two ounces of bread and four ounces of meat the night previous, and two cups of tea and some toast an hour before execution. It contained—

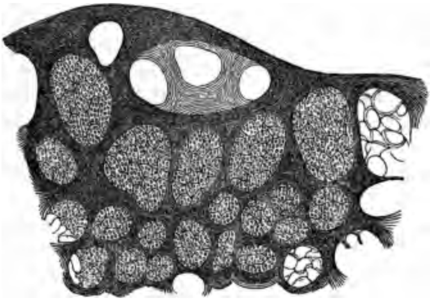
Water	90·48
Albumen and fibrin	7·08
Water extractive	0·56
Osmazone	0·52
Alkaline phosphates, chlorides, carbonates, and chlorides and oxide of iron	0·44
Fat	0·92
	100·00

Traces of sugar can also be discovered in chyle and in very minute amount in lymph. The chyle of lower animals is often combined with blood, and even in man that from the upper part of the thoracic duct is very often pink, and becomes red on exposure to air. The fat gradually decreases; the fibrin, white cells, and molecular base increase as it passes upwards.

The Discovery of lymphatics has been claimed for *Joliffe* and also for *Bartholin*, who described them in 1652. They spread through every tissue in a manner like the drainage of a country. None have been demonstrated in nervous matter or the organs of sense. Those of the limbs are in 2 sets, superficial and deep, running along with the veins and passing through axillary and inguinal glands to terminate in the thoracic duct. Their course can be displayed by injection, especially in a thin or dropsical subject. The coats of lymphatics are transparent, and consist of 3 layers: 1, an areolar; 2, intermixed elastic and muscular fibres; 3, an epithelium, composed of spindle-shaped cells. Semilunar valves with their concavity towards the heart occur in pairs, and the vessel being much distended above them, and narrow below, has a beaded appearance. A valve is always found where they enter a vein. These coats are elastic, and contractile in about the same degree as veins. *Ruysch* long since asserted he could inject lymphatics from blood vessels, and the converse has been maintained, so that the only communication is not that at subclavian vein. *Kölliker*, whose representation is here copied, describes the lymphatics as beginning in the tissues by fine pointed vessels, arranged in a stellate form, and although apparently, closed, blood cells enter, perhaps by rupture.—During impeded respiration they often regurgitate into lymphatics from the veins. The lymph is moved by a vis a tergo, by the contraction of the vessels, and, as discovered by *Müller*, by lymph-hearts in reptiles and some birds.

The commencement of the Lymphatics, with two Stellate Cells in the act of uniting.

The absorbent glands are oval, firm bodies of a pink colour, save when stained by the absorbed matters, being thus black from carbon about the lungs, yellow from bile about the liver, and white from chyle in the mesentery. The lymphatics entering the gland (vasa inferentia) are smaller than those leaving (vasa efferentia), which are always less numerous, and there may be but a single vessel. The outer coat of the vessels supplies a capsule which dips into the interior of the gland. Mercury, when injected, shows that the vessels appear to twist up; and it is believed that the coats of the vessels do not remain perfect but break into spaces, freely communicating with each other, and supplied by numerous blood-vessels on the outer surface. This cellular appearance was long since noticed by *Nuck* and *Abernethy*. The epithelium of the lymphatic spaces in the gland is constantly generating abundant oval nucleated cells, which *Goodsir* believes are shed into the current of the lymph. The absorbent power of lymphatics is best shown by the imbibition of the syphilitic virus and of animal poisons, as that from dissecting wounds, which produce tracks of their course in the angioleucitis, and inflammation, hardening, or suppuration of the glands through which they pass. Cinnabar has been found in the axillary glands of a man who had tattooed a figure with it on his arm years before. The skin owes its great absorbent power to the lymphatics, which it contains most abun-



Structure of a Lymphatic Gland.

dantly; it will take up water, according to *Madden*, who found he gained over half an ounce in weight by remaining for half an hour in a warm bath; and there are instances of jockeys becoming heavier in a moist air. If a frog be kept in a damp atmosphere it will become more plump, and the bladder will become loaded. Such substances as garlic, madder, gallic acid, are more readily absorbed by lymphatics than by veins in the skin, as the former are more numerous and have such thin coats. We have seen the reverse to hold good in the intestines.

Lymph is a colourless fluid consisting of cells like the white blood-cells floating in the "liquor lymphæ," which only differs from the liquor sanguinis in having much less fibrin. This constituent is increased by passage through glands, after which the lymph will coagulate if removed from the vessels—never while it remains within them. The daily quantity of lymph and chyle which is poured into circulation, is said to amount to 28 ℔ by *Bidder* and *Schmidt*, 22 ℔ being the proportion of the lymph. From 3 to 5 ℔ has been collected daily from a wounded lymphatic in a horse's foot.

Dr. Rees gives the following comparative analysis of lymph and chyle from the ass:

	Lymph.	Chyle.
Water	96·536	90·237
Albumen	1·200	3·516
Fibrin	0·200	0·370
Extractive	1·559	1·565
Fat	a trace	3·601
Salts	0·585	0·711
	100·000	100·000

The uses of lymph cannot be said to be positively known. *Hunter* regarded it as effete matter; *Carpenter* thinks it may be pabulum removed from one part for the nutrition of some other part; thus the materials of our own body, as well as the flesh of other animals, may serve us as food. Lymph may, perhaps, consist merely of the plasma of the blood, poured out in tissue-making, and returning by a new channel, and *Dr. Graves*, in 1828, termed the lymphatics "the veins of the white tissues." The absorbent glands are thought to be concerned in the elaboration of fibrin or white blood-cells, and it has often struck me that lymph is conveyed to them to afford the materials.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Describe the process by which fluids permeate porous bodies.
2. Sketch the lacteal system.
3. State the composition and supposed uses of lymph.
4. In what tissues and organs are lymphatics most, and least abundant?

SENIOR.

1. Detail Graham's discoveries on the subject of "dialysis."
2. How do medicines enter the circulation, and what classification of them is made according to their physiological action?
3. Describe the chemical and microscopical characters of chyle.
4. What changes does lymph undergo in its passage towards the veins, and how is its flow in that direction produced in man and other animals?

THE BLOOD.

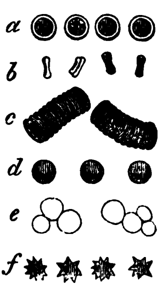
By the two great processes we have described in the last chapters, food is assimilated and added to the blood, which is constantly being exhausted by the formation of tissues and secretions. The blood annually carries about 3,000 ℔, or a ton and a-half of pabulum for these purposes, and returns a like amount to the various emunctories by which effete matter is discharged. Its composition is truly complex, some 40 different substances being found in it, but its ultimate analysis corresponds closely with that of flesh. *Bordeu*, then, justly called it "la chair coulante."

We shall consider this most important fluid under the following heads: I. Quantity; II. Physical and microscopical characters; III. Chemical composition; IV. Vital properties.

I. **The quantity of blood** in man's body has been very variously stated. *Harvey* guessed it as $\frac{1}{20}$ of the weight of the body; but *Haller* more justly stated, that judging "from profuse hemorrhagies, there will be 28℔ of true red blood current in the arteries and veins, of which the arteries contain only one-fifth and the veins the other four." *Weber*, by injecting, calculated the amount to lie between 11 and 15 ℔, but *Valentin* adopts a more reliable method. He draws a quantity of blood and determines its per-centage of solid residuum; he then injects a definite quantity of water and withdraws a second portion of blood, in which he ascertains the loss of solid constituents. In this way the weight of blood is counted as $\frac{1}{5}$ that of the body, which averaging 140℔, will leave the amount of blood at 28℔, the exact amount which *Haller* assigned. The male body, which weighs most at 30 years, according to *Quetelet*, will contain more, and the female body, which is heaviest at 50 years, somewhat less. If a known quantity of a harmless and easily tested salt, as ferrocyanide of potassium, be injected into a vein and then some blood drawn, the proportion of salt in it will also afford a rough estimate. This method, as well as *Valentin's*, is vitiated by the rapidity with which the injected matter may be removed by skin, kidney, &c. *Bernard* finds that there is nearly double as much blood about two hours after food as during fasting, or at least he can remove twice as much without the animal dying. This suggests the plentiful administration of food to those who may have to lose blood in surgical operations or warfare, and its exhibition in diminished and divided quantity in plethoric diseases.

II. Physical and Microscopical Characters. Blood, as it flows from a divided vessel, is an opaque, red, viscid fluid, of an average specific gravity of 1·055 according to *Nassé*. Its reaction is alkaline, and it emits in cooling an odour peculiar to each species or even each individual, somewhat like that of the perspiration, and which is much increased by the addition of sulphuric acid. Blood becomes acid when kept by the conversion of its sugar into lactic acid. It appears to be homogeneous, but the microscope shows that it consists of cells floating in a fluid, termed the plasma, or liquor sanguinis. The cells are of two kinds, red and white.

The Red Cells were first described by *Malpighi*, who saw them in the hedgehog and regarded them as fat globules. *Swammerdamm* is said to have observed them in 1658, some years previous. They may be examined in any transparent tissue, as web of frog's foot, or wing of bat, or in a drop of human blood if diluted by any fluid of like specific gravity, as solution of sugar. In undiluted blood they are obscured by over-crowding. Singly their colour is yellow, but if aggregated they give the red colour to the whole fluid. They are bi-concave, circular discs, like so many coins, measuring on an average $\frac{1}{3300}$ in diameter and $\frac{1}{3}$ of that in thickness, or $\frac{1}{10000}$. They are then so minute, that it is calculated 5,055,000 of them would fill but $\frac{1}{16}$ of a cubic inch. Their surface is figured at *a*, and they are seen edgewise at *b*. They are so thin in the centre as to have appeared to *Munro*, *Abbé Torré*, and others, as perforated like quoits. By the addition of water they swell by endosmose, become biconvex (*d*), and transparent (*e*), and disappear probably after bursting. *Gulliver*, in his lectures before the Royal College of Surgeons, London, states that water does not dissolve them, as they re-



Red Cells under various conditions.

appear on adding bichloride of mercury; an aqueous solution of iodine has a similar effect. By adding a denser fluid, as gum solution, they are seen to shrivel, becoming corrugated or even serrated at the edge (*f*). Saliva also produces a crenate outline, and acid sherry makes them throw out tail-like fibres.

Hunter regarded these bodies as fluid all through, like oil drops, save that they never ran together. *Beale* has advanced a somewhat similar opinion; but that they consist of a cell-wall and contents, as first stated by *Hewson*, may be still confidently maintained from the effects of various reagents. There is a nucleus in them only during fœtal life, and in those of pregnant women. *Busk* found a nucleus once in man, and they normally occur in the elephant, horse, and other animals. *Wharton Jones* states that the adult cell is but the nucleus, the cell-wall being destroyed. *Kölliker* thinks the nucleus disappears, and the cell-wall remains.

The red cells are developed in the germinal area before any trace of heart or glands appears, and are then large, spherical, and colourless, containing a nucleus and granular matter like fat. They multiply by a transverse fission, and during the next stage they gradually assume a flattened form and red colour, the nucleus still remaining. At the 3rd month of fœtal life they are fully developed as bi-concave, red, non-nucleated cells, and are henceforward supplied by transformation of chyle and lymph cells. These latter are spherical, rough, and darkly shaded, but are converted stage by stage into the red blood cells. These changes have been admirably investigated by *Paget*, who notices the advantage of this mode of renewal over production from germs, as loss of blood would then be more injurious, by removing both cells and their germs. The temporary states of man's blood-cells remain permanent in many animals, as is likewise the case with regard to the phases of development of all the organs. Their characters are peculiar in each class, but are capable of change by the influence of domestication. They are very similar to those of man in all mammals save the camel tribe (the dromedary, llama, alpaca, &c.), in which they are oval, as in birds, reptiles, and fishes. *Gulliver* gives the following measurements for some mammals:

Elephant	$\frac{1}{2700}$	Ox	$\frac{1}{4200}$
Sloth	$\frac{1}{2800}$	Cat	$\frac{1}{4400}$
Man	$\frac{1}{3000}$	Sheep	$\frac{1}{5300}$
Ape	$\frac{1}{3400}$	Goat	$\frac{1}{6300}$
Dog	$\frac{1}{3500}$	Musk Deer	$\frac{1}{12000}$

The proteus anguinus has, according to *Carpenter*, the largest cells, measuring $\frac{1}{337}$, but *Harting* states those of the crypto-branchus somewhat exceed them.

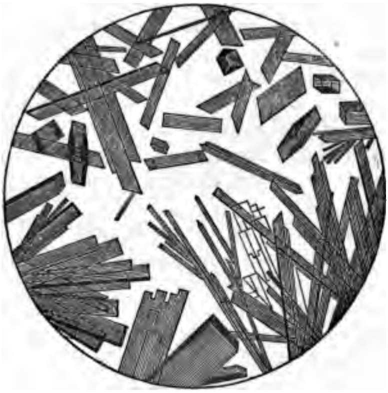
The wall of the cell is so tough and elastic that they may be seen to squeeze through capillaries smaller than themselves, and regain their shape when freed from pressure. They often adhere by their surfaces into piles like rouleaux of coins, as discovered by *Wharton Jones*. This appearance, which is figured at *c*, page 107, is normal in the horse, and frequent in inflammatory blood, promoting coagulation. While being examined under microscope, they often move about, owing to the evaporation of the fluid, and the heating effect of light upon it. *Schultz* regarded these movements as analogous to those of the particles of sap, which in characeæ produce a kind of circulation or cyclosis; and *Carus* believed that the blood-cells moved through the blood-vessels by a power inherent in themselves. Such movements, and contraction, and dilatation are best seen in the white cells. From the resemblance of blood-cells to amæba and other monads, they were once supposed to be infusorial animalcules. A parasite, which *Bilharz*, its discoverer, named distoma hæmatobium, exists in blood. The red cells are composed of a wall of globulin, and the matter within is called hæmatin, the chemical relations of which have been already stated. *Muller* states hæmatin is composed of, in 100 parts, carbon, 65·84; hydrogen, 5·37; nitrogen, 10·4; oxygen, 11·75; iron, 6·64, which last element exists probably in the unoxidised state, as chlorine or sulphuric acid will remove it, and it is not acted on by hydrochloric acid, as the oxide or carbonate would be. *Liebig's* opinion that iron exists as a carbonate of protoxide of iron in venous, and peroxide in arterial blood, is well known. The iron in blood was discovered by *Menghini* by its exhibiting magnetic properties.

The colour of blood is not due to iron, as it remains after its removal, and the blood of many invertebrates contains it, yet is colourless. As *Henle* first stated, the colour depends on the gases which the blood contains. Thus, carbonic acid in venous blood distends the cells, and thus allows the dark-coloured hæmatin to be more apparent through their thinned walls; oxygen, on the contrary, shrivels the cells, and gives the lighter scarlet tint. Exposure to these gases alternately will produce the change from modena to scarlet nine or ten times, after which the cells are destroyed, or at least lose this power. That the change of colour is rather due to mechanical than chemical effect, is shown by no alteration occurring in a mere solution of hæmatin. *Draper* regards the change of indigo from yellow to blue by the absorption of oxygen, and from blue to yellow by its expulsion, as quite analogous.

The main function of the red cells is to act as "carriers of oxygen" to the tissues, which are thereby oxidised, and returned in the venous blood as carbonic acid, urea, water, and other effete products, meanwhile setting free caloric. Their number is proportional to respiratory activity, save perhaps in cæruleans. It has been stated that a precipitate of what the microscope shows to be red cells, falls, when streams of oxygen and carbonic acid are passed through a solution of hemato-crystallin: if this be so, they are clearly a product of respiration. That it is the red cells have this power of absorbing, is shown by blood taking up from 10 to 13 volumes of oxygen; whereas, when deprived of cells only one volume, or the same amount as pure water holds, will remain. The oxygen is so easily parted with that it was believed to be not chemically combined, but in a state of loose association; but *Schönbein* has announced the significant fact that it is converted into ozone, an allotropic form of oxygen. Other functions, not fully understood, are alluded to by *Lehmann*, who regards red cells as laboratories in which the individual constituents of the plasma are prepared for the higher function of aiding in the formation and reproduction of the tissues, or, floating gland cells secreting hæmatin.

When these minute organisms have fulfilled their functions, they are supposed to be cast off, probably by the liver, as there is much similarity between the colouring matter of blood and of bile. *Prof. Draper* exclaims, "It is sufficient to arrest our thoughts at once, when we learn that for every beat of the pulse, 20 millions of these organisms die. Physiology has its passing wonders as well as astronomy." That they are not very rapidly reproduced, appears from the decrease of their numbers for a long time after full venesection. *Dalton*, however, regards them as permanent structures, suggesting that no anatomical element is ever destroyed, but merely proximate principles.

The well-defined characters of the red cells render their detection by the microscope easy, of which advantage is taken to ascertain the presence of blood in diseased products, and in stains on weapons, dress, &c., in medico-legal investigations. Their appearance, if moistened with serum, or a fluid of like specific gravity, even after being dried up for months, is a much surer indication than chemical tests. The peculiar size and characters of the cells of lower animals have also given aid in judicial inquiries. The beautiful crystals which, as *Funke* discovered, the matter of the red cells forms, are also readily recognized for such purposes, especially if treated with acetic acid, when they assume a rich, dark brown. Human blood crystals, as here delineated, are prismatic; those of other mammals tetrahedral and hexagonal. They are decolorized by chlorine. They occur in clots from aneurism and apoplexy, and may be produced by breathing on a drop of blood spread on glass, when the carbonic acid seems to promote their formation.



Human Blood Crystals.

The White Cells were discovered by *Bauer*, and are less numerous than the red in about the ratio of 1 to 800; being increased, however, after taking albuminous food, during pregnancy, in early life, and after loss of blood. In certain diseased conditions they may attain the proportion of 1 to 7, or even more, as represented on the frontispiece. They are larger than the red, being about $\frac{1}{2500}$, and are spheroidal, pearly or cloudy, and rough on the surface. They are very uniform in size among animals, being pretty equal in the proteus and musk deer, the extremes as regards the size of red cells. When observed in the capillaries they seem to roll lazily along the sides, occasionally adhering as if they were glutinous, whereas the red ones rush through the centre of the vessel. Their exact chemical composition is undetermined, as they cannot be separated from fibrin. Their use is not known positively, but they are supposed to nourish the albuminous tissues, and *Donné* states they are composed of albuminous particles $\frac{1}{8000}$ in diameter agglutinated together. They are also regarded as being identical with lymph and chyle cells, and as becoming changed probably in the ductless and absorbent glands into the red cells. Their number increases as we descend the animal scale. The frog has the proportion of 1 to 16 red cells in the month of February, and 1 to 6 in August (the reason of this variation not being apparent). The amphioxus has no red cells, nor have the invertebrates, whose nutritive fluid is more like chyle.

Some pathological investigations I have been engaged in, induce me to consider the white cells and fibrin as identical. It is acknowledged by the most able analysts that they cannot be separated, and when the fibrin is removed by whipping blood, no white cells can be found in the remaining fluid. In many morbid states of the blood, inflammatory, tubercular, or leucocythemic, and in that of the herbivora, the microscope shows the white cells to be over-abundant, and analysis determines the fibrin to be proportionally in excess. *Addison* believes that the fibrin is contained as fibrillæ in the white cells, and when blood is drawn, they burst forth, and arrange themselves in the closely-matted state we call fibrillation. This condition, from its analogy to gelatinization and crystallization, appears to be more an evidence of death, or return to inorganic state, than organization.

As before alluded to, *Donné* states white cells are composed of albuminous particles; now, these may by further oxidation become fibrin, and the cells bursting may allow the particles to assume the thread-like form. This would suggest that coagulation is attended by, or may be due to oxidation—a view which the necessity for free exposure to air strengthens. The coagulation of albumen by nitric acid may be also due to oxygen, which that substance so readily affords, converting it into an amorphous form of fibrin. There are most white cells between the opening of the thoracic duct and the lungs, where oxidation gives rise to fibrin. In inflammatory blood there is often a layer of white cells between the red clot and the buffy coat, where they cannot be exposed to the action of the air. *Virchow* states that fibrin as such is never an exudation from the blood, which, however, contains matter readily convertible into it by local causes. Inflammation of parts freely supplied with lymphatic vessels and glands, as lung, pleura, liver, &c., is a most fruitful source of increase of fibrin, whereas phrenitis scarcely alters the amount, and it is known the brain possesses few if any lymphatics. He also has shown that lymph-fibrin differs from blood-fibrin in never coagulating within the vessels, as it has not as yet met with air; it does so when exposed to the atmosphere. *Denis* and *Lecanu*, from chemical considerations, support the view that the cells contain fibrin. *Carpenter* believes that the white cells develop fibrin, or convert other albuminoids into it; and there is scarcely any fibrin in the chyle in its earlier stages of development, or till it is passed through the mesenteric glands, where the white cells are known to be generated.

The point we are now discussing involves the question "whether is fibrin or albumen the higher in the scale of organization?" and we shall briefly state the arguments which have been advanced on either side. *Zimmerman* first started and *Simon* ably supported the doctrine, that fibrin was merely effete matter, as it exists in such small proportion to the albumen, and it is nearly absent from portal blood, which we know must carry back the nutrient matter which results from digestion. Hepatic venous blood contains it more abundantly. Its amount is proportionally increased in anemia, exhausted states of the system—where the waste has exceeded the supply—by starvation, and after bleeding. *Andral* and *Gavarret* showed that improvement in the breed of animals diminished its proportion. Moreover, there is little or none in fœtal blood, that of carnivora, chyme, or in the egg, which of course are highly nutritive. The property of fibrillation is very analogous to gelatinization, as fibrin first forms a jelly-like mass out of which fibrils develop, and to which it can be again reduced artificially or within the body, as we see in aneurismal clots. Mucus also, a substance acknowledged to be in a state of regression, has similar jelly-like and fibrillous stages. *Liebig* says fibrin may be "perhaps albumen, half converted into gelatin." Its existence in very small quantity in the blood of ceruleans supports the same view, as in these individuals, like cold-blooded animals, there is but little waste. Fibrin is more easily converted than albumen into urea by *Bechamp's* method. According to the theory now propounded, the gradation would be albumen, syntonin, fibrin, gelatin, urea. On the other hand, the excess of fibrin in arterial blood, that substance having more nitrogen than albumen, according to *Dumas*, and the fact that 2 or 3 per 1,000 is found permanently in the blood, whereas urea, creatin, and other effete matters are at once removed, convince some physiologists that fibrin is the true nutrient pabulum of the tissues. The question is far from settled. We shall return to it when treating of blood diseases.

III. **The chemical composition** of many substances in the blood has been before alluded to. We shall therefore in this place merely state the proportions they exist in, and their most important relations. The following table, arranged from the analyses of *Lehmann*, exhibits the composition of blood, and separately of the cells and plasma, from a healthy man aged 25. Its specific gravity was 1·060, and it contained 513·02 parts of cells to 486·98 of plasma:

	Blood.	Cells.	Plasma.
Water	788·71	349·69	439·02
Hæmatin (including 0·512 of iron)	7·70	7·70	
Hæmato-crystallin	127·54	127·54	
Fibrin	3·93		3·93
Albumen, Fat, and Extractive	64·24	24·35	39·89
Chloride of Potassium	2·062	1·887	0·175
Chloride of Sodium	0·701		0·701
Sulphate of Potash	0·205	0·068	0·137
Phosphate of Potash	1·202	1·202	
,, Soda	0·457	0·325	0·132
,, Lime	9·193	0·048	0·145
,, Magnesia	0·137	0·031	0·106
Soda	0·921	0·175	0·746

Playfair assigns as a formula for both blood and muscle, $C_{45} H_{39} N_6 O_{15}$.

The Water must vary hourly with the state of the skin and kidney and the hygrometric condition of the atmosphere; yet very surprising uniformity is maintained, as *Bence Jones* showed, by keeping one dog without water and the other drinking freely for months; still the blood of both was of the same specific gravity. Venesection increases the relative quantity of water, but has no power to reduce fibrin or to prevent exudation in inflammation—hence the low estimate of its value now entertained: that last drawn has the lowest specific gravity, the serous fluid of the tissues being sucked up. There is more water in women's than in men's blood.

The Albumen gives greater viscidity to the fluid, and by its very low diffusive power prevents exudation. *Becquerel* and *Rodier* state that dropsy occurs when its proportion is less than 6 per cent. It does not impair the diffusion of substances mixed with it in the blood, for the common salt, urea, and sugar pass through animal membrane as freely as if they were dissolved in pure water. Albumen is kept dissolved by union with soda, or the tribasic phosphate of soda, which also dissolves phosphate of lime and gives the alkaline reaction to the blood.

The Fibrin is generally counted with the white cells, as they cannot be separated. There is more in arterial than in venous blood, as the oxygen in the former produces it from albumen. The blood of the porta has very little fibrin.

The Fats are olein, margarin, cerebrin, cholesterin, and serolin, which was believed to be a peculiar fat, but it is lately stated to be but a mixture of common fat and albumen. The odour of blood is said to be due to a peculiar volatile fatty acid.

As regards the mineral components, they are shown in due proportion in the preceding table, and it will be seen that the cells contain much more phosphorus and potash than the plasma, and thus seem destined for the nervous and muscular tissues.

The Gases in the blood are oxygen, nitrogen, and carbonic acid, and it will absorb from 10 to 13 volumes of the former, irrespective of sea-level.

It will be understood that the blood is ever changing its composition, containing materials in a state of formation, maturity, and decay. "They are mixed together, past, present, and future—the blood of yesterday, the blood of to-day, and the blood of to-morrow—and we have no method of separating them."

Electric properties were assigned to the blood by *Dutrochet*, who even stated that he could form muscular fibre from albumen by galvanism—assertions, however, disproved. Electricity reddens venous blood, as also do most neutral salts, especially those that afford oxygen.

Arterial and Venous Bloods differ materially, unless the aeration of the arterial has been interfered with, as in hot countries, under the influence of chloroform, ether, or opium; when blood has been kept delayed in the vessels, as by a tourniquet, or when it flows from a deep wound; under all these circumstances, both that from artery and vein are dark-colored. On the contrary, venous blood coming from a gland in action, as the kidney or the parotid, has been shown to be scarlet, but of the ordinary hue when no secretion is occurring. The reverse is the case in the blood coming from a muscle, which, if contracting, sends out dark blood; if at repose, sends out the arterial blood unchanged in colour. These effects are due to the production of carbonic acid. The main differences are here tabulated:

ARTERIAL.	VENOUS.
Scarlet, not dichromatic.	Modena or purple, but green, in very thin layers, being dichromatic.
Temperature, about 100°	Temperature, about 98°
Denser, and hence greater capacity for heat.	Lower specific gravity.
More fibrin and red cells.	More albumen.

IV. **Vital properties.**—We have seen that blood within the vessels consisted of cells floating in the plasma, or liquor sanguinis; when, however, it is withdrawn, another arrangement takes place, the fibrin leaving the plasma and uniting with the cells to form a solid mass. This phenomenon is called coagulation, and was first accurately described by *Harvey*. The solid mass is termed crassamentum or clot; the fluid, serum, which still contains albumen; and if this be removed, the fluid is termed serosity. Coagulation then produces a rough, spontaneous analysis, as shown by the following table:

FLUID BLOOD	Plasma	Serum	Albumen Water Salts	COAGULATED BLOOD.
		Fibrin	Clot	
	Cells ……………			

In from 2 to 7 minutes after withdrawal, the blood becomes solid; colourless drops of serum then ooze out, and the clot becomes firmer and smaller, till, at the end of from 24 to 48 hours, it is but ¼ the bulk of the serum. These changes, with the respective proportions of the clot and serum, are represented here in a bowl of blood, and may be contrasted with the figure on page 122. The following conditions respectively favour or retard coagulation:

Coagulated Blood.

Rest; though the fibrin will clot when the blood is whipped with twigs.	Motion.
Roughness of surface; as caneæ columnæ of heart, valvular irregularities, or lacerated wounds.	Smoothness; hence fluidity within the arterial or venous coats.
Exposure to air; by flowing in a slow stream, or into a shallow vessel.	Exclusion of air; by rapid stream, tall vessel, or a film of oil.
Moderate temperature.	Heat of 160° by coagulating albumen, or cold of 32° by freezing blood; but it will coagulate, if thawed, many months after.

An extreme amount of fibrin delays coagulation—thus, the blood drawn in a case of pneumonia did not coagulate for a week, and putrefaction was proportionally retarded.

It is prevented by neutral salts—hence their use in acute rheumatism to prevent clots on valves of heart—by an alkali, as soda, in the proportion of 1 to 1,000 parts of blood; by bile, solution of opium, acids, even that of the vaginal mucus; for if menstrual fluid is removed from the uterus by a speculum, it coagulates. The blood does not clot after death by lightning, electric shocks, excessive exercise, as in animals hunted to death, according to *Hunter*, but *Gulliver* doubts this conclusion; also after death by blows on the stomach, fits of anger, asphyxia, alcohol, hydrocyanic acid, and other poisons. The blood drawn by a leech, and even that flowing after it is removed, does not coagulate—hence the difficulty of stopping bleeding from its bite.

The Cause of Coagulation has been a much debated question. *Hunter* vaguely said: "My opinion is, that it coagulates from an impression—that is, its fluidity under such circumstances being improper, or no longer necessary, it coagulates to answer now the necessary purpose of solidity." That it is not the lower temperature to which the blood is exposed when drawn into air, he showed by that of a fish, which is at 60° while the animal lives, clotting when exposed to air of a higher temperature. His opinion that it was "an operation of life" is expressed by *Harvey* when he calls blood "primum vivens, ultimum moriens." That some attempt at organization is made seems supported by the following facts—1. The clot assumes the definite form of very minute interlacing threads, such as we find in lowly organized structures, as the membrana putaminis, or lining of egg-shell, effused lymph, &c. 2. The clot is imperfect under the same diseased conditions in which lymph is aplastic. 8. It often coagulates, as the first step towards organization, as seen in the conical clots above and below a ligature upon an artery. The organization of cerebral clots and false membranes, and of blood effused into joints, which is supposed to give rise to foreign bodies, are analogous occurrences.

Gulliver objects to regarding coagulation a phenomenon showing any evidence of vitality, for he says, after being exposed for 57 weeks to nitrate of potash or to a freezing temperature, blood will coagulate; and, he remarks, "we cannot freeze and pickle life;" but the term vitality may be applied to blood in the same sense as we apply it to a seed, in which the capability of germination will lie dormant for centuries. Coagulation is prevented by contact with the surface of living vessels, for if a glass tube be inserted between the blood and the vessel, it at once occurs; whereas in the vessel between ligatures it remained fluid twenty-five hours.

Coagulation, then, would seem to be a vital process, which, under more favourable circumstances, would proceed to organization. *Draper* regards it the same process as that which is constantly occurring in tissue-making, save that the cells are not entangled, the fibrin being picked out by muscular tissue as fast as presented. That coagulation is due to fibrin cannot be doubted, for if it is removed by disease, or artificially by twigging, the blood no longer clots. The red cells in the frog are so large that they will, as discovered by *Müller*, remain on a filter, and the plasma, which passes through, still clots. Strong solution of sulphate of soda will prevent the human blood-cells from passing through a filter. *Bernard* has lately stated that blood from which all fibrin is abstracted by whipping, and renal blood which contains none, may be made to coagulate, which may be due to the conversion of the white cells by oxidation into fibrin. The investigations of *Dr. B. W. Richardson* have demonstrated that the coagulation of blood depends on, or is attended by, the evolution of ammonia. It is remarkable that the *Hon. Robert Boyle*, in 1684, stated the blood evolved a "spirit," and discovered that an ammoniacal salt would preserve its fluidity, and that the blood coagulated when it was evolved. *Haller* proved the vapour from blood to be alkaline: "Deinde de effuso sanguine volatile aliquid et halituosum aufugit cum odore quodem inter fœtorem urinæ et sudoris odorem medio. Id, vasis idoneis receptum aquosum adparet cum levi alcalinæ indolis quasi tinctura. Hac halitu emisso sanissimi hominis sanguis sponte cogitur in tremulam scissilem massam." We know that albumen is kept fluid by another alkali, soda, which, however, not being volatile, requires to be removed by an acid. *Richardson* shows that a microscope glass wetted with hydrochloric acid, and held over recently drawn blood will be covered with crystals of hydrochlorate of ammonia. They may be also obtained if the cupping-glass be moistened with acid, before being placed over the incisions. Coagulation is prevented by adding ammonia, by preventing its escape, or by exposing one vessel of blood to the vapour of another. The clot will re-dissolve if treated with ammonia, and re-coagulation occur if it is allowed to volatilise. One part of ammonia will keep about 3,000 of blood fluid. It will be seen that nearly all the circumstances favouring or retarding coagulation are explicable on this hypothesis, which has been, however, opposed by *Lister*, as blood kept fluid by ammonia will still remain so if that alkali be neutralised by acetic acid. This objection does not possess much weight, as the neutral salt thus formed has the power of hindering coagulation. The resemblance of coagulation of fibrin and the contraction of muscle, and its arrangement in fibrillæ, were remarked by *Hunter*. The coincidence of coagulation, rigor mortis, &c., support this view. I regard the formation of urea (which is metameric with cyanate of ammonia) by muscles when contracting, and the evolution of ammonia when blood is coagulating, as also analogous. The clot sometimes assumes a yellow colour for half an inch or so of its surface, and becomes also concave. This condition is called the "cupped and buffed coat," and depends usually on the proportion of fibrin being absolutely or relatively increased, when coagulation takes place more slowly, and the red cells have time to sink to the bottom. It is most frequent in

Blood—"Cupped and Buffed Coat."

inflammatory blood, but no mistake founded on false deductions from physiology was ever more fatal in practice than that of supposing it afforded an argument for the lancet, as anemia will also produce it, the cells sinking readily through the thin blood. It may occur during pregnancy, and when the system is excited by night-watching, &c. The serum which oozes from the buffy clot will often coagulate itself. The arrangement of the cells in piles tends to produce the buffy coat.

Transfusion of blood was first performed by *Lower*, in 1665, and was used therapeutically by *Blundell* in cases of uterine hæmorrhage. *Bérard* cites 15 cases where life was saved. Animals bled to syncope are revived by injecting blood still containing red cells, for mere serum produces no effect. The fibrin should be separated, as otherwise its coagulation would interfere with its introduction, and *Dr. B. Ward Richardson* advises that ammonia should be added to the blood about to be transfused. It is generally stated that blood containing circular cells is fatal to birds and other animals whose cells are oval, but *Bischoff* asserts this is only true of venous blood which acts like a rapid poison, but arterial blood may be transfused without injury. The greatest care should be taken to prevent the entrance of air. Saline solutions have been injected with impunity, and *Stevens* proposed it as a cure for cholera. The animal from which the blood is abstracted should be previously fed, as it will then sustain the loss more easily, and the proportion of the vivifying element, the red cells, will be increased—that of the fibrin diminished; and, indeed, *Bernard* has found that the blood of a starving animal acts as a poison; for, if transfused into another animal it dies with symptoms of putrid resorption.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. What is the average amount of blood in man's body, and how has it been determined?

2. Describe blood as it flows from a vein.
3. What is the diameter of the smallest and largest blood cell, and of that of man?
4. Mention the relative size and number of the white and red cells of the blood.
5. Compare arterial and venous blood, noting the circumstances under which the difference may not be apparent.
6. State the circumstances which promote, retard, or prevent the coagulation of the blood.

SENIOR.

1. On what grounds can you advise the free administration of food before capital operations?
2. Sketch the microscopical characters of the red cells under various conditions.
3. What do you know of the development of the blood-cells?
4. Arrange a table of the components of the blood showing their respective proportions in the serum and clot.
5. Adduce proofs that the coagulation of blood depends on the removal of alkali, and suggest some curative deductions.
6. What precautions should be adopted in transfusing blood?

CIRCULATION.

When the nature of the offices which the blood performs is understood, it must be evident that a necessity exists for its distribution to every part of the body. Leaving the left ventricle, it traverses the aorta and every other artery, passes through the capillaries to the veins, and thus ultimately returns to the right auricle. This is the greater or systemic circulation. The blood then passes to the right ventricle, thence through the pulmonary arteries to the lungs, the great organs for purification, after which the pulmonary veins return it to the left auricle. This is the lesser or pulmonary circulation, and is succeeded by the systemic one again. The vena portæ, as will be explained hereafter, presents the peculiarity of ending in a second set of capillaries, instead of, like other veins, in a trunk.

These facts are now known so generally that it is hard to conceive how slowly each of them was discovered. Physiologists, at first, believed the arteries to be empty, that the cavities of the heart communicated, and the veins carried the blood through the body; but *Galen*, who lived about A.D. 150, maintained that the arteries carried blood, wrongly guessing that air was taken in for cooling the blood. *Vesalius* proved there was no communication between the sides of the heart. He suffered punishment and much odium, for having opened the body of a young nobleman dead some hours, the heart being found still beating. *Servetus* next discovered that the blood flowed from the right side of the heart, through the lungs, to the left; and this pulmonary circulation was re-discovered by *Cæsalpinus*, who first applied the term "circulation." It was reserved for our immortal *Wm. Harvey* to prove the course of the blood through the system, which he did in 1619; but afraid of the scorn of his contemporaries, he delayed publishing his discovery till 1628, when his "Exercitatio Anatomica de motu cordis et sanguinis" was given to the world. He relied on the following proofs:—In bleeding, the vein swells below the ligature, and the blood flows from the side of the orifice farthest from the heart—the contrary being the case with an artery; again, the direction of the valves of the heart and of the veins, which he had seen his master, *Fabricius*, first demonstrate at Padua. The actual observation of the blood in the capillaries gave further proof; *Malpighi* made this discovery in 1661—but with *Descartes* and a few others he had long supported *Harvey's* doctrine, and defended it from the envious attacks of narrower minds.

The organs concerned in circulation are the heart, arteries, capillaries, and veins, in which order we shall describe their functions.

I. **The Heart** must be regarded as the most perfect of machines, as it executes with unsleeping activity some three thousand millions of beats, propelling about five hundred thousand tons of blood in the course of an ordinary life. Its descriptive anatomy we shall not attempt, but refer with pleasure to a masterly account in the late lamented *Prof. Power's* work on the "Heart and Arteries." It is essentially double in adult life, consisting of one auricle and ventricle on the right side presiding over pulmonary circulation, and two similar cavities on the left performing the systemic circulation. The heart is mainly composed of muscular fibres, very similar to those of voluntary muscles in structure, colour, and tendinous attachment, but peculiar in the following particulars:—They are of but ⅓ the size, according to *Skey;* their myolemma is so fine as, till lately, to have escaped detection, but it is evident in true fatty degeneration of the heart; they interlace, bifurcate, and anastomose, and do not lie on the same plane, but pursue a spiral direction. In hearts hardened by boiling and alcohol *Searle* has traced two kinds of ventricular fibres—"proper," which form two sacs open towards the arterial mouth and at the apex; and "common," which surround both ventricles, and entering through the open ends of the sacs form the inner surface of the ventricles. From the manner in which the fibres mat together, a smooth surface and not a fibrous appearance is obtained by section, as seen well in a roasted sheep heart. To trace the fibres *Mr. Ledwich* selects an infant's heart, and prepares it with a solution of corrosive sublimate and alum. White fibrous tissue is found round the auriculo-ventricular openings, extending into the active valves round the arterial mouths and their semilunar valves, and scantily in the Eustachian valves in right auricle. The heart is covered by a smooth membrane, the pericardium, to facilitate its own movements, and lined by a fine epithelium, the endocardium, to facilitate the movements of the blood. The organ is abundantly supplied by the 2 coronary arteries, whose blood is returned to right auricle by a single coronary vein.

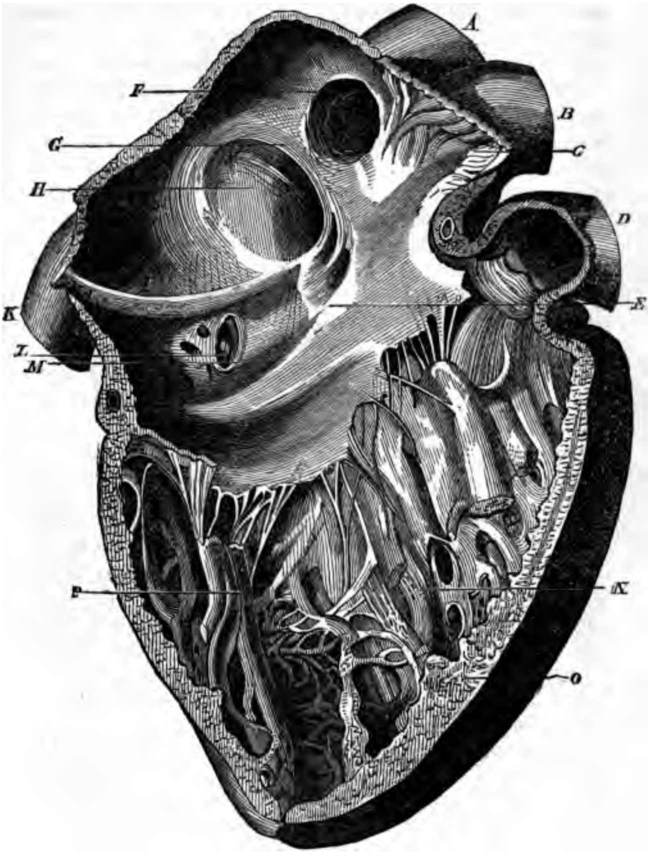
The Nervous Supply is derived from the 3 cervical ganglia of the sympathetic, pneumogastric, recurrent laryngeal, and perhaps phrenic nerves. The nerves form one great, and many minute plexuses, and are finally distributed round the coronary arteries. The pneumogastric appears to be the motor nerve, as its destruction arrests the motion of the heart. The ganglion of *Wrisberg* lies in the arch of the aorta; and between the ventricles and in the muscular tissue, especially in the hearts of the calf and the frog, *Remak* has discovered many ganglia. Those described on the surface of the ventricles by *Lee*, are probably mere thickening of neurilemma.

The Actions of the Heart will be best understood by following the course of the blood, remembering, however, that the 2 auricles and 2 ventricles are synchronous; that is, the contraction or systole of the right ventricle, occurs at the same time as that of the left, and their diastole or dilatation correspond also, and similarly the auricles.

When the right auricle has gradually filled from the cavæ and coronary vein, it suddenly contracts, and the cavæ being filled and the coronary vein being closed by its valve, the blood rushes into the right ventricle. However, some blood is thrown to the large veins, producing the "venous pulse."

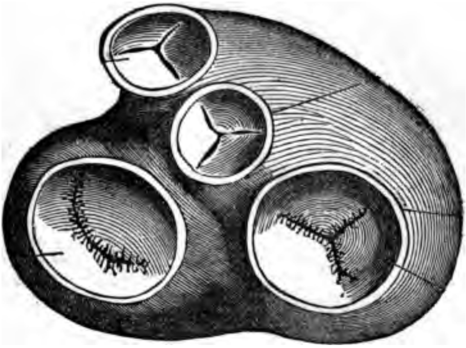
The right ventricle, when full, contracts and propels the blood into the pulmonary artery, its passage back into the auricle being prevented by the tricuspid valve. This is closed by the pressure of the blood tending towards auricle, and, as *Haller* saw in the heart of a living animal, by the shortening of the papillary muscles, which many believe, merely prevent the valves being thrown into auricle. That some reflux was allowed by the incomplete apposition of the flaps of the tricuspid valve, occurred to *Hunter*, who says: "The valves in the right side of heart do not so perfectly do their duty as those of the left." This was again stated by *Mr. Robert Adams*, and still more fully described by *Mr. W. King*. This anatomist showed, that the anterior or "yielding" wall when thrown forward, pulled with it the anterior and right flaps of the valve, which he calls "curtains of distension," and allowed regurgitation. Any undue separation is prevented by a "moderator band," which runs from the yielding to the fixed wall or septum. Were it not for this hydraulic imperfection, rupture, which, as it is, never occurs here, would be risked, and over-distension of the cavity would lead to its paralysis, a condition which we shall see occurs in asphyxia. The auricles do not empty themselves as perfectly as the ventricles. The valvular apparatus of the right side and some other structures of the heart, are illustrated by the figure on opposite page.

After aeration the blood proceeds from the lungs through 4 pulmonary veins to left auricle, where no valves exist; and thence into left ventricle, where the mechanically perfect bicuspid valve allows no leakage, and rupture has occasionally occurred at the rete cordis near apex. This powerful cavity gradually contracts, and the blood rushes through aorta and the whole arterial system, to be again returned to the right side of the heart. The aortic valves, like those of the pulmonary artery, offer no obstruction, as they are thrown back against the walls of the vessel when the blood is rushing out; when, however, it falls back, some gets behind them and they are forced together, effectually closing the aperture. The corpora Arantii are of use in keeping the edges of the valves out from the aortic walls, thus letting the blood behind the valves, in strengthening them, and perhaps filling the interval which the 3 valves might leave between them. As *Savory* has shown, the valves are



Right side of Heart. A. Superior Vena Cava. B. Aorta. C. Musculi pectinati. D. Orifice and Sigmoid Valves of Pulmonary Artery. E. Right Auricle. F. Orifice of Superior Vena Cava. G. Annulus of Vieussens. H. Fossa Ovalis. I. Eustachian Valve. K. Inferior Vena Cava. L. Orifice of Coronary Vein. M. Thebesian Valve. N. Carneæ Columnæ. O. Wall of Ventricle. P. Musculi Papillares.

supported underneath by the ventricular wall. The annexed figure exhibits the four great valves closed, and the relative positions of the orifices from left to right. The auricular systole is sudden, being but $\frac{1}{8}$ as long as the diastole; the ventricular gradual, as more resistance has to be overcome. The diastole of both is gradual, and is believed by many to be passive, or produced by the force of the cavity behind contracting; and by others to be active, or dependent on the dilating power of the cavity itself. This view *Cruveilhier* supports, for he found that if the empty heart of an animal just dead were grasped in the hand, considerable dilating force was perceived during diastole.


The Orifices and Valves of the Heart—Mitral, Pulmonary, Aortic, Tricuspid.

Two sounds accompany the heart's action, and are audible to the observer, or, in some cases, perceptible to the individual. Thus *Müller*, when lying on his left side, could distinguish those of his own heart. The following occurrences take place during

1st Sound	and	2nd Sound
Ventricles contract		Ventricles dilate
Auricles dilate		Auricles dilate,

and an interval of repose succeeds during which the auricles contract. *Cruveilhier* is of opinion that no pause is appreciable; and on the contrary others believe there is one after each sound.

The First Sound is systolic, and is best heard over the apex of the heart, as there no lung muffles it, and the heart comes near the surface by the impulse which occurs at the same time. It is a dull, rumbling sound, and so prolonged as to occupy as much time as the 2nd sound and the pause. Thus, if the heart be beating 60 times per minute, the 1st sound occupies ½ a second, the 2nd sound rather less than ¼, and the pause rather more than ¼. The time occupied by the action and repose of the ventricles is thus calculated by *Walshe* in tenths of a second:—systole, 4; post-systolic silence, 1; diastole, 2; and post-diastolic silence, 3. As regards its cause, it is but the "bruit musculaire," or noise, which the heart, in common with other muscles, produces in contracting. *Dr. Halford*, Professor of Physiology in Melbourne University, states that this noise is in part produced by the vibration of the air in the stethoscope or auditory meatus, placed on the chest. A similar sound may be heard during contraction of the biceps, masticating muscles, or, as *Wollaston* suggested, by placing the little finger in the ear and rapidly moving the thumb. It has been objected to this theory, which was maintained first by *Williams*, that it is not proportionally increased in hypertrophy of the heart, but in such cases the superficial fibres—muscle being a bad conductor of sound—muffle the bruit produced by the deep. The weak heart in typhus produces scarcely any sound. Tension and vibration of the auriculo-ventricular valves, as suggested by *Billing* and ingeniously supported by *Halford*, the impinging of the heart's apex against the chest, the collision of the particles of the blood against each other and against the rough columnar surface of the ventricle, and the rush through the narrowed arterial openings, have each been assigned as the cause of the first sound, and they may all in some degree contribute.

The Second Sound is diastolic, or corresponds with the filling of the ventricles, and is most audible at the base of the heart. It is a sudden, flapping sound, somewhat like the lapping of a dog. It is certainly due, as suggested by *Sir R. Carswell*, to the flapping together of the semilunar valves at the aortic and pulmonary apertures. This is proved by *Hope's* experiment, repeated by a committee of the British Association which met in this city in 1834, and included *Drs. Adams, Law, E. M'Dowel, Evory Kennedy, Carlile*, &c. They hooked up one of the aortic valves with an awl, in an animal whose heart was kept acting by artificial respiration, and found a hissing sound took the place of the second sound, which again occurred if the valve was let back. Disease often presents, as it were, an experiment by nature, and in that affection termed "permanent patency of aortic valves," of which *Dr. Corrigan*, has given an original and exhaustive account, no second sound occurs, as the valves do not act. *Williams* compares the sounds of the first and second sounds respectively to the syllables "lubb," "dup." It might be expected that the sounds would be heard more distinctly on opening the thorax of a living animal; but, on the contrary, they become almost inaudible. The same fact was illustrated in the remarkable case of M. Groux, who exhibited himself before the medical societies in 1857-8. His sternum was congenitally cleft, and, as if that bone played the part of a sounding-board, his cardiac sounds were very low. Many other points were investigated in this individual, and the systole and diastole of the cavities were demonstrated by the sphygmascope, which consists of a tube containing water, and closed by a soft piece of india-rubber at one end, dilated into a bell-shape. He was able to increase the width of the cleft to 3 inches by the action of the pectorals. Several important observations were made by a committee in this city, and are recorded in the report drawn up for the Royal Irish Academy by *Prof. Lyons* of the Catholic University.

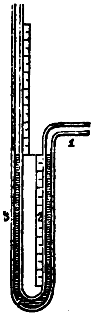
The Impulse is the stroke which the hand perceives if placed over the precordial region, between the fifth and sixth ribs, about 1½ inches below the nipple. It is synchronous with first sound, and just precedes the pulse. It was caused, according to *Hunter*, by the rush of blood straightening the aortic curve; but it will occur if the aorta be empty, and *Dr. Corrigan* remarks that the heart would be thrown to the right side by the direction of the aortic curve, and not to the left, as it is. That great physician and able physiologist believes the impulse due to the simple swelling forward of the muscular substance of the heart. In the cat, rabbit, or other narrow-chested animal, the impulse can be felt on both sides of the chest. Others state it is due to the heart elongating and pressing its apex against the wall of the chest, producing, according to some, a friction sound. *Harvey* suggested this when he says, during contraction, "the heart is erected and rises upward to a point, so that at this time it strikes against the breast, and the pulse is felt externally;" but the heart really shortens during systole. It has been also suggested that the reactionary force produced by the discharge of the blood into the aorta may give rise to the impulse. The late *Prof. Carlile*, of Queen's College, Belfast, suggested that the anterior fibres, which are longer than the posterior, would tilt the apex forwards. *Dr. Bellingham* described a second impulse synchronous with the second sound, which occurs in the healthy heart when beating vigorously, or in the hypertrophied condition.

The Rhythm, or the regular succession of the actions of the heart, is one of its most remarkable properties. It has been stated to be due to the stimulus of the oxygen in the arterial blood and *Goodwin* regarded the absence of this stimulus to be the cause of asphyxia;

Brown-Séquard has advanced a contrary view, viz., that carbonic acid is the special stimulant of the heart's action. The heart will, however, act in vacuo. The ganglia about the organ are believed by *Paget* to preserve this regularity of action by rhythmic nutrition, and it continues to contract when removed from all other nervous influence. The irritability of the heart is very great, and appears to be inherent. It lasts much longer in cold-blooded animals, and in the hybernating longer than the wakeful state of some others. An American author states, that if removed from a sturgeon, the heart will beat till it becomes dry and rustles. Even portions of the heart deprived of blood and excluded from air will contract rhythmically. Such can hardly be explained by any irritability being accumulated in the organ, as electricity is in a Leyden jar. The nervous system has, however, great power over the action of the heart, and thus great shocks and irritation can be transmitted to the organ. A case has occurred where an enlarged bronchial gland, by pressing on the great cardiac nerve, produced cessation of action for 4 or 6 beats, and fearful symptoms like those of angina pectoris. That the heart's action can be controlled by the will would appear from the case of Colonel Townsend, reported by *Dr. Cheyne.* This individual could stop his pulse and respirations, so that a vessel filled with water was not spilled if placed on his sternum, and no vapour was deposited on a mirror held before his mouth. Irritability deserts the right auricle last, which has been therefore styled "ultimum moriens." The heart, although acting regularly, has intervals of repose equal to the period of its contraction; and thus some other muscles, as those which preserve the erect posture, act for nearly as many hours out of the 24.

The force of the Heart is no doubt the chief motive power of the circulation, and such terms as "primum mobile," "vis a tergo," have been applied to it. A somewhat less force than that which has been calculated for the power of the left ventricle, would inject water through the whole vascular system. That the heart is not the sole cause of the circulation is shown by the fact of the blood moving in the embryo before a heart appears; in cases of fatty degeneration, where it becomes almost powerless; in acardiac fœtuses, as in the remarkable example observed by *Houston;* and in many of the invertebrates, where no enlargement on the blood vessels analogous to a heart exists. *Valentin* calculates that the force of the left ventricle is equivalent to 3 ℔, that of the right to half that amount. To demonstrate the force of the heart, *Hales* adopted a plan which had been in use in measuring the force of rivers. His instrument was a brass tube joined by a goose's windpipe, selected for flexibility, to a glass tube. He inserted the brass tube into the carotid of a horse, and found the blood rose about 9½ feet, varying with the height of the animal. He in this way determined that the left ventricle would sustain a weight of 113 ℔.

For such investigations, *Poisseuille* invented the hæmadynamometer, which is here represented, and which consists of a glass tube having a small, straight arm inserted into the vessel, then bent into 2 vertical portions. Mercury is introduced into the tube, and between this and the vessel, to prevent the coagulation of the blood, a solution of carbonate of soda. The height to which the mercury is raised is shown by a scale attached, and is a measure of the force in the arteries. He found that 8 inches of mercury were supported, and its specific gravity being 13·5, this is very nearly equivalent to 9 feet of blood, and would correspond to a pressure of 4 ℔ 3 oz. in aorta, half that in pulmonary artery, and gradually less



The Hæma-dynamometer. 1. *End inserted into Artery.* 2, 3. *Bent portion containing Mercury.*

for the small arteries; thus, 4 drachms for the radial artery. *Poisseuille* believed the arterial force to be everywhere alike, and detailed some experiments made in 1860 which support this view; but *Volkmann* asserts that it varies even between the cardiac and distal end of the one vessel. The column of mercury rises during systole, falls during diastole, and is affected also by respiration, rising during expiration and falling during inspiration, the blood rushing towards the partial vacuum made in the chest. During inspiration the radial pulse often stops, which has been attributed to the pressure of the lungs on the subclavian arteries, for the temporals are not much influenced, the lungs being unable to compress the trunks they come from.

My revered predecessor in St. Vincent's Hospital, *Dr. Bellingham*, found that the weight required to compress the femoral artery in his method of curing aneurism, varied between 4 and 6℔.

The velocity of the blood in arteries was much exaggerated by *Hales*, who calculated the rate in the aorta as 735 feet per second. *Volkmann*, however, with the hæmadrometer (a glass tube doubly bent and filled with water) has reckoned the average rate in the carotid as but 12 inches per second, gradually decreasing through the whole arterial system, and being augmented by systole, especially if vigorous. We shall see that the pulse-wave, and salts introduced into the blood, travel very much faster. *Valentin* calculates that if the amount of blood be 18℔, and the amount expelled by the left ventricle at each contraction 3 oz., it would take 96 strokes to send the blood one complete round, which, at the rate of 72 beats, would occupy 1¼ minutes.

The Pulse, although more immediately a phenomenon belonging to the arteries, can be more conveniently considered here. It is the stroke which the finger perceives if placed over a superficial artery, and which indicates the rapidity, force, and regularity of the heart's action.

It is due to the wave jerked from the heart, producing a vibration on the sides of the vessel, being greater as these are elastic, though it would likewise occur in a rigid tube. *Bichat* thought it owing to the vessel being raised out of its bed, as seen in the tortuous temporal artery of old people. Tonicity of the vessels makes it travel faster, but that it is not caused by a vital property of the artery, may be shown by joining a piece of artery from a dead animal to that of a living one, and the pulse will be felt in both; and in varicose aneurism, where the arterial blood passes into the veins, these vessels pulsate. The pulse varies in frequency with (1) age, as seen in *Dr. Guy's* tables. At birth 140, childhood 100, adult age 75, old age 70, or according to many accurate observers, very much lower; thus, *Heberden* found it 26, and *Fordyce* 20 per minute. (2) Sex—that of female being 5 or 10 beats more frequent. (3) Time of day—the pulse falls gradually throughout the day, and most rapidly towards night. (4) Sleep renders it much slower. (5) Posture—being greatest in the erect, next in the sitting, and least in the recumbent position. This fact was noted in 1784 by the late *Dr. Macdonnell* of Belfast, who named the variation "differential pulse." *Dr. Graves* also investigated the subject, and found the variation might range from 6 to 15 beats per minute in health. The change is due to the greater muscular exertion in the two first postures, requiring more blood and pressing on that in the veins, as shown by experiments with the revolving board, by which these positions can be obtained without muscular exertion. The alteration, for like reasons, is greater in males. *Dr. Guy* found it in:

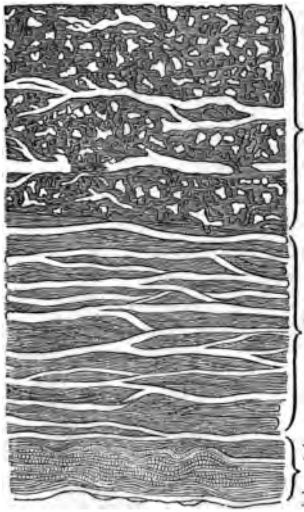
	Standing.	Sitting.	Lying.
Males	81	71	66
Females	91	84	80

(6) Stature—being slower in tall persons. The rapidity of the infant pulse is mainly due to this circumstance.

(7) Ingestion of food quickens the pulse, especially during the act of eating. (8) Diminished atmospheric pressure increases it; thus, the pulse which was 70 at the level of the sea, was 75 at an elevation of 3,000 feet, and so on, till it arrived to 110 at 13,000 feet above the sea. *Dr. Frankland* found his pulse double its normal frequency at the summit of Mont Blanc. A vigorous mind is often accompanied by a rapid pulse, but not invariably, if, as reported, Napoleon's was but 44 per minute. Through the animal kingdom the pulse varies most widely, being but 7 in the shark, 200 in the heron.

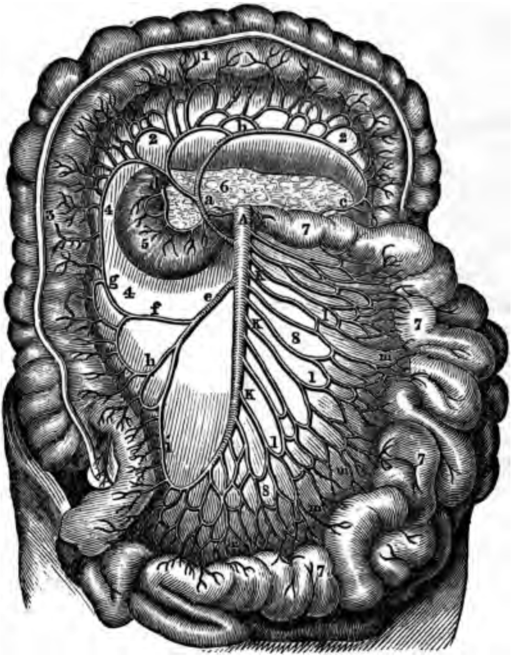
The Development of the Heart is best studied in the chick. It appears about the 30th hour of incubation as a curved tube, receiving posteriorly 2 or 3 veins from the germinal membrane, and branching anteriorly into 2 trunks which unite below the vertebræ into the aorta. On the 3rd day it consists of a sinus venosus, ventricle, and bulbus aortæ, the two first becoming gradually divided by septa, and the latter forming vascular arches. About the 7th day the cavities join together, and the bulb is divided by a septum into aorta and pulmonary artery. The pulsations begin before muscular tissue or even a cavity can be discerned, the heart being a mere cellular mass, or "punctum saliens," as *Harvey* termed it. In the human heart the ventricular septum grows from above downwards, between the 4th and 8th weeks.

II. **Arteries** were so named from being supposed to carry air, as they are found empty after death. They are cylindrical tubes when full, and so elastic as to remain so when empty. They consist of 3 coats: 1. The external one is composed of areolar tissue serving to connect the vessel to other parts, and to afford a sheath for the passage of the vasa vasorum, which are derived from neighbouring vessels, according to *Hunter*, and the nerves which twine round the artery like ivy round a tree ("hederæ admodum"—*Scarpa*). It is tougher than the other coats, remaining when a ligature or false aneurism has ruptured them. 2. The middle coat is of a buff colour and is made of two elements—the elastic, abounding in the large arteries, and the muscular in the smaller. The yellow elastic fibres are arranged in an outer circular layer, which constitutes $\frac{5}{10}$ of the whole thickness of the vessel. This is mixed up with branching or penniform fibres of *Todd* and *Bowman*, whose section is here copied, and organic muscular fibres. Still more elastic tissue is arranged in longitudinal fibres, that just under the lining membrane, of which it is the basement layer, being the "fenestrated coat" of *Henle*. 3. The inner coat consists of long epithelial cells with distinct nuclei, and is in immediate contact with the blood, which must nourish it and receive the epithelial cells as they are exuviated. Morbid alterations occur in and under this membrane.



Section of middle-sized Artery.

Arteries divide into gradually smaller branches at a right angle near the heart, and obliquely far from it, where the force is diminished; and as the area of the branches is mostly greater than the trunk they spring from, the whole arterial system assumes the form of a cone. This enlargement is best marked in small arteries, where the area almost doubles; whereas in the common, external, and internal iliac arteries, *Paget* states a diminution actually occurs. The communication, or



The Arched Ramifications of the Superior Mesenteric Artery.

anastomosis of arteries is accomplished by the direct joining of two trunks into one, as vertebrals; by their being connected by intermediate vessels, as at the circle of *Willis;* by dividing so as to form arches, as in the mesentery. The figure on opposite page shows this method of anastomosis, which prevails in all the digestive viscera. Still more frequently, arteries communicate by small branches being given off, which join those from the vessel lower down, or from the opposite side of the limb. It is such inosculations which are so useful in preserving the collateral circulation if by disease or ligature an artery becomes obstructed.

The Elasticity of the arteries *Hunter* proved by the following experiment: "A circular section of the aorta ascendens, when slit up and opened into a plane, measured 5½ inches; on being stretched, it lengthened to 10½ inches; the stretching power being removed, it contracted again to 6 inches, which we must suppose to be the middle state of the vessel." This property diminishes with the size of the vessel; the muscularity increases. Suppose an artery full of blood, the systole of the left ventricle must force more blood in, and this must be accommodated by the forcing of the blood onwards into the capillaries, or by the increase of diameter of the artery, which, as may be calculated by placing an elastic metal ring round the vessel, is equal to $\frac{1}{23}$ of its previous calibre. During the succeeding diastole the elasticity of the artery re-acts on the blood, and the aortic valves closing, the stream must be moved onwards. Insufficiency of supply and gangrene of a limb will follow if elasticity is impaired, as by the calcification of the artery. By elasticity also the intermitting pulsations of the heart are converted into a constant stream, as achieved in the common fire-engine by a like elasticity of the hose. The blood, however, from a divided small artery jets "per saltum," showing that a perfectly uniform current is not obtained. If a canula be inserted into the ventricle of a living animal, the blood will also jet out, but if it be inserted into the aorta, which is so elastic, a uniform flow occurs. An equable and prolonged supply is also obtained by the artery breaking up into many minute branches, which again re-unite, as seen in the "rete mirabile" of *Galen* on carotid and vertebrals of animals which graze, preventing congestion; in the rete ophthalmicum of birds; in the arm of the sloth, which allows the animal to remain suspended by the limbs for hours; and in the leg of the swan, goose, &c., which permits prolonged standing. The same object is attained by great tortuosity, as in the seal, where the carotid is nearly 40 times longer than the space it traverses. During systole arteries become much more tortuous, and this condition becomes permanent in old people, as their arteries harden. The coats of the vessel are always thicker at its convexity.

The Irritability of the arteries was also shown by *Hunter* in the following and many other experiments: "The posterior tibial artery of a dog being laid bare, and its size attended to, it was observed to be so much contracted in a short time as almost to prevent the blood from passing through it, and when divided, the blood only oozed out from the orifice." Besides air, as in this case, electricity and mechanical stimulus will excite muscular contraction in the smaller arteries, and if applied at interrupted points will actually produce a monilar or beaded appearance. *Müller* denied these statements, grounding his opinion on the structure of very large arteries. The usual tests also show the presence of an albuminoid, which fibrous tissue has not. Muscularity of the arteries does not afford much propelling force, but rather regulates the due supply of blood to any part. It does not therefore exist in large arteries, as no cause requiring an increase or decrease of blood could be so general as to affect all the parts to which, for instance, the brachio-cephalic artery sends blood. It is owing to the suspension of this tonic power that increase of blood is allowed in erectile or occasional organs. Contractility will remain for even 48 hours after death, as in the famous experiments of *Hunter* on the umbilical cord, and thus renders the injection of a subject more difficult at this period. Irritating fluids will pass with difficulty through vessels recently deprived of life, but bland ones will pass with rapidity and ease. The sympathetic nerves supply the irritability, as contractions can be produced by irritating them. Cold increases, heat decreases tonicity. Rhythmical pulsations have been observed in the arteries of the ears of rabbits, analogous to those which *Wharton Jones* discovered in the veins of the bat's wing, and, like them, not synchronous with the cardiac or respiratory movements.

III. **The Capillaries** were discovered, in 1661, by *Malpighi*, and till then there was a gap in *Harvey's* theory. Their name does not express their fineness, as they measure but from $\frac{1}{1000}$ to $\frac{1}{4000}$; the smaller are found in retina and brain, the larger in liver and lungs, which are here figured. They preserve the same width through the whole length from artery to vein. *Wedemeyer* denied their separate existence, stating the artery joined the vein merely by canals hollowed in the substance of the tissues they permeate. High microscopic power has, however, proved that they have distinct walls, but has failed to exhibit any structure in such coats, which are therefore similar to cell-wall and sarcolemma. A nucleus is sometimes seen in them. The question of the vascularity or non-vascularity of certain tissues is but one of degree, for even in the most vascular the capillaries do

Capillaries of Lung.

not penetrate their ultimate elements; in muscle, for example, they pass between the fibres, external to the sarcolemma. Their distribution follows the anatomical arrangement of the various tissues, and when those of the muscle, the skin, stomach membrane, villi, &c., are injected, they are easily distinguished, and form some of the most brilliant of microscopic objects. On the surface of the body their distribution is very unequal, a circumstance which but serves to enhance by contrast the beauty of the fair bosom and of the blushing cheek.

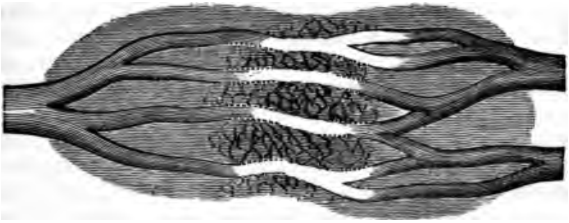
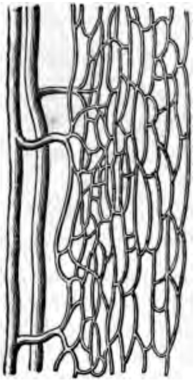
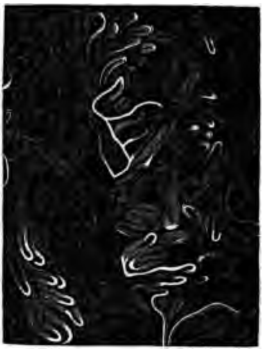


Diagram to illustrate the Tubular Spaces which, according to Wedemeyer, unite the terminal arteries and veins.



Artery, Vein, and Capillaries of Muscle.



Capillaries of the Papillæ of a ridge of the skin.

Capillaries are intermediate between arteries and veins, save in the erectile tissues, uterus, and in the bat's wing, according to *Paget*—a statement, however, denied by *Wharton Jones*, another most accurate observer.

The microscope, when any transparent part—as the web of frog's foot—is placed within its field, displays the capillary circulation, a sight full of wonder and interest. It is here roughly sketched the arrows distinguishing the artery and vein; and in the next woodcut a vein is perceived lying out of focus. Fancy a map, with all its rivers and their minutest tributaries to be set flowing. The larger capillaries admit 3 or 4 blood-cells abreast—the smaller but 1, which has even to squeeze and elongate before it can pass to a large vessel, when it becomes circular again. The condition of water in rivers is analogous to that of blood in capillaries, for the current through the centre is far more rapid than that at the sides. In this "still layer" the white cells lie, apparently ministering to nutrition. They keep so distinct that it was once supposed the red cells flowed through a second tube within the capillary. The width of the still layer is about ⅛ that of the entire vessel, and is increased by cold,

Artery, Vein, and Capillaries of Web of Frog's Foot.

Capillaries of Frog's Web.

decreased by heat. The rate of the flow in the centre is said to be 1⅔ inches per minute by *Volkmann*, and as the rate through arteries is probably 700 inches per minute, he calculates that the entire area of the capillaries must be 400 times that of the arteries they spring from. Capillaries may be seen to contract either by elasticity after distension, or by muscularity, an endowment which the nuclei in the walls would suggest they possess. That the capillary circulation depends on the heart is argued on the following grounds: 1. The pressure on the sides of the veins, as in the arteries, is derived from the heart and must be sent through the capillaries. 2. Pressure on the main artery soon enfeebles the capillary circulation. 3. In fishes the heart forces the blood into the aorta through the capillaries of gills. And lastly, a pulse wave may be seen in the capillaries in some cases of debility, probably owing to a thin state of blood.

Capillary Force, or the "vis a fronte" produced by the interchanges between the blood in the capillaries and the tissues about them, is explained by *Draper*, who for many years has enunciated the following law: "If 2 fluids communicate with one another in a capillary tube, for the substance of which they have affinities of different intensities, movements will ensue; the liquid having the highest affinity will occupy the tube, and may even drive the other before it." This law has the advantage of universality, as it explains the movements of the sap in the vegetable kingdom, the force of which is shown by the following experiments: divide the stem of a vine, and tie a piece of bladder over the cut surface, when it will be burst by the sap ascending from the roots; and if the upper segment be placed in water, that fluid will be sucked up, as long as under the influence of light the formative action of the leaf goes on. The rate of the circulation in pulmonary capillaries is 5 times as great, so much chemical interchange occurring, as that in the systemic; and *Draper* therefore regards respiration as a most powerful cause of circulation. The exclusion of oxygen removes this cause of circulation, asphyxia resulting, as in drowning, inhalation of nitrogen, hydrogen, or other negatively injurious gases. This capillary force accounts for the following facts more clearly than can any vis a tergo, such as the heart: 1. The empty state of arteries after death. 2. Movement of blood in the early embryo and acardiac fœtus in animals without a heart, and after the heart has been removed or aorta tied. 3. The portal circulation. 4. Periodic and local variations, as those produced by mental emotions, blushing by shame, blanching by fear; local inflammations, congestions and fluxes, and the effect of cold; and lastly, such changes in the lungs as are produced in asphyxia and the first inspiration. This force also explains those occurrences expressed by the aphorism, "ubi stimulus ibi fluxus," of which the increased flow to a gland when about to secrete, and to a part when about to inflame after the application of an irritant, are examples. Many other instances will be adduced when we are discussing the pathology of inflammation, and it will be shown, that they are mainly due to the regulating influence of those cerebro-spinal and sympathetic nerves which constitute the vaso-motor system.

Erectile Tissue is but a mass of capillaries shorter and more freely communicating than usual. It is found in the corpora cavernosa of penis and clitoris, in the nymphæ, vagina, and nipple. Its turgescence is excited by either local irritation or by emotion conveyed through nervous system. *Kölliker* thinks its erection due to the removal of nervous influence, which had before kept the calibre of the arteries contracted by their muscular coat, which is always highly developed. This view is supported by the fact of priapism occurring in paraplegia, and by erection being retarded by cold, promoted by heat. Some abnormal examples of this tissue which I have met with, will be mentioned.

The Veins collect the blood from capillaries, and gradually enlarging, pour it through the cavæ into the right auricle. They are arranged in two sets—superficial, which have no corresponding artery; and deep, of which two usually accompany an artery, its venæ comites. When full they have a cylindrical form, but not so uniformly as arteries, and they are dilated into pouches above the valves. The coats are similar to those of arteries, but much thinner, and even transparent, the colour of blood appearing. In the cavæ near the heart, striped muscular fibres are continued from the auricle. *Kölliker* has not found muscular tissue in veins on the uterine side of placenta, in those of brain, dura mater, diploe, corpora cavernosa. At variable distances valves are found usually in pairs, and always with their free semilunar edge turned towards the heart. Valves are numerous in superficial veins, scarce in deep and large ones, and absent in the portal, pulmonary, and renal systems, and those of bones. Although there is three times as much venous as arterial blood, its proportionally slower circulation transmits about an equal quantity of each through a part in a given time. The rate of flow is very equable, as we see in venesection, and is more rapid the nearer it approaches the heart. That the heart affects the current is evident from its producing "the venous pulse," and which occurs mainly when the blood is thin, as in anemia, and by the flow being so much retarded by pressure on the main artery. This force is, however, but $\frac{1}{12}$ of that of the accompanying artery.

Respiratory movements influence venous flow, for during expiration the veins become turgid, as seen in dyspnœa, and are emptied by next inspiration, the blood rushing towards the partial vacuum. *Sir D. Barry* showed this by inserting a tube in the jugular vein of a horse, when a coloured fluid was raised through it at each inspiration. This would only occur in the veins near the thorax, and would be prevented by the collapse of such soft tubes as the veins. In the fœtus, also, and animals which swallow air, circulation occurs, and yet no respiratory movements aid it. During expiration, arterial pressure is at its maximum, and then apoplexy, rupture of aneurisms, and increase of inflammatory pains are apt to take place. *Carson* supposed the right auricle had a "suction power" by its wall, or those of pericardium being pulled asunder by inspiratory movements, or by the resiliency of its walls after contraction, like the expansion of an india-rubber bottle. Muscular contraction assists the flow through deep veins, as seen by the greater constancy of the current when the limb is moved during venesection, but which is partly due to the greater quantity of blood a part receives while acting than while quiescent. All expenditure of force in a backward direction is prevented by the valves. The venous circulation is very much under the influence of gravitation, and if the tone of the vessels be deficient, great delay to its return may occur. The practical surgeon daily perceives this in the effect of long standing in producing varicose veins, and the beneficial effect of an elevated posture of the limb in treating ulcers upon it. *Lower* records a case where varicose veins were so dilated, and the circulating force so weak, that the patient fainted whenever he stood up, the blood gravitating to his extremities. It may be well if we recapitulate:

The Forces of the Circulation.

1. Contraction of the heart, or vis a tergo.
2. Elasticity of the arteries.
3. Muscularity of the arteries.
4. Capillary force, especially in the lungs.
5(?). Movements of the blood-cells themselves, as stated by *Carus* and *Treviranus*.
6. Pressure of the muscles on the veins.
7. Inspiration.
8(?). Expansion of right auricle, according to *Carson*.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Sketch the course of the circulation, and say by whom its pulmonic and systemic portions were first demonstrated.
2. Why does the left ventricle rupture more frequently than the right?
3. Compare the cardiac sounds.
4. What instruments have been used to determine the force of the circulation?
5. Describe the structure of arteries and mention some experimental proofs of their elasticity and contractility.
6. In what vertebrates can the capillary circulation be demonstrated by the microscope?—Describe it.

SENIOR.

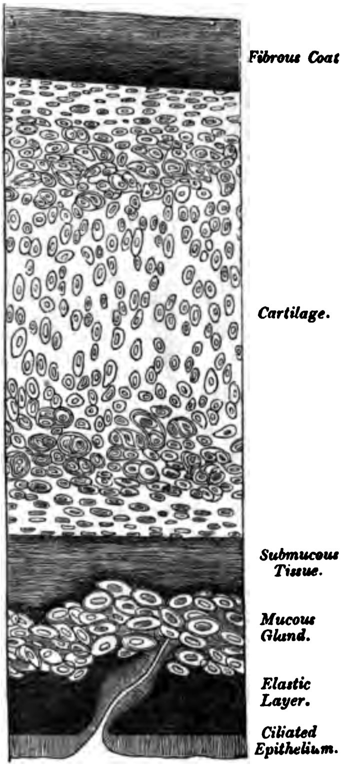
1. Enumerate the proofs of the circulation.
2. Describe the fibres of the heart, including the points in which they differ from those of voluntary and from other involuntary fibres, and from both.
3. Sketch the mechanism of the arterial valves, and mention what supports them underneath.
4. What chiefly produces the first sound of the heart, and with what other cardiac actions is it synchronous?
5. With what circumstances in health may the frequency of the pulse vary?
6. What evidences are there of a circulatory force in the capillaries?

RESPIRATION AND ANIMAL HEAT.

The physiological processes we have heretofore considered, are for the purpose of forming the tissues of the body from the blood. That fluid becomes loaded with results of the destructive combustion of the old tissues, and is freed from them by the means which this chapter and the next treat of.

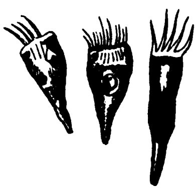
Respiration, then, is a process of excretion by which carbonic acid and superfluous water are discharged, but is also the means by which oxygen is introduced. In plants the interchange is reversed, carbonic acid by them being absorbed as food and oxygen evolved. Animals are either air-breathing or water-breathing, according to the medium in which the exchange takes place.

We shall first describe the structure of the respiratory organs. Air is admitted through both mouth and nostrils, and being raised to a temperature approaching that of the lungs, is conducted to the trachea. This tube extends from the 5th cervical to the 2nd dorsal vertebra, and is about 6 inches long and ¾ wide. It consists of about 18 or 20 rings, each forming ⅔ of a circle, the tube being flat behind where they are deficient. They are set in a strong fibrous sheath, which being continued between them and behind them, forms the most essential part of the tube, and it is the first and most universally developed. The ends of the rings are connected across by unstriped muscular fibres—the



Coats of Trachea.

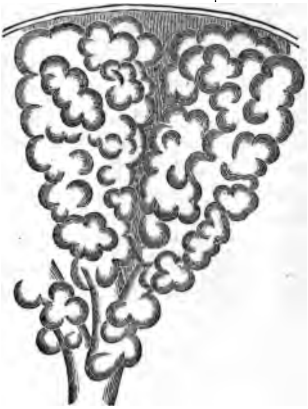
"trachealis," a striped muscle in birds. It can narrow the tube, which for that purpose is deficient in cartilage behind, and not merely to allow the œsophagus to distend into it. Within these structures the tube is lined by branching longitudinal, elastic fibres, which continue into the bronchi, and is finally coated by ciliated mucous membrane, one offset of the gastro-pulmonary tract. The cilia of the whole pulmonary tract produce a current upwards, excluding particles of dust and expelling mucus and air; but they must, in returning to the perpendicular, introduce fresh air. There are from 10 to 22 on each epithelial cell in man, but less in those of other animals. The tracheal glands are tubular like the sweat glands, and dip into the elastic coat and trachealis at the back of the tube. They exhale an odorous, watery vapour.



Ciliated Epithelium of Trachea of the Cat.

The two bronchi into which the trachea bifurcates divide in the lungs dichotomously, or in binary order, and doing so produce, according to geometrical progression, many thousand tubes whose diameter averages about $\frac{1}{80}$. As the bronchi become smaller, the rings gradually disappear; but the muscular, elastic, and ciliated coats last to the terminal tubes.

The lungs are made up of the air cells in which the bronchi end, grouped into lobules, which can be recognized as polyhedral masses on the surface. These lobules, like those of a racemose gland which the lung much resembles, are joined by areolar tissue, the parenchyma, and constitute 2 lobes in the left, 3 in the right lung. The whole organ is covered by a smooth, serous envelope, the pleura, which overcomes friction, and an areolar capsule, which is continuous with the parenchyma, and which, by its elasticity, considerably aids expiration. The air-cells of one bronchus do not communicate with those of another, but the blood-vessels lie between them and send branches to contiguous lobules. When the tube is near its termination it loses muscular tissue and the epithelium, unless the latter be so fine as to escape microscopic detection, as *Rainey* suggests. *Radclyffe Hall* maintains its existence. In some animals the air-cells are so small as to be incapable of containing a single epithelial cell. The tube ends by dilating into a conical form, the lobular passage or infundibulum of *Rossignol*, from the sides of which the air-cells bulge off, and which are thus separated by partitions containing the capillaries exposed to air on two surfaces. Two infundibula, the air-cells which project from them, and the areolar space which separates them, are here figured. *Moleschott* asserts there is muscular tissue in the walls of air-cells. The lobular passages measure from $\frac{1}{10}$ to $\frac{1}{200}$, the air-cells from $\frac{1}{200}$ to $\frac{1}{400}$. There are about 1700 cells from one tube, and thus about 600 millions in both lungs. The surface of the lung is enormously increased by this arrangement of cells, and has been calculated at 1,400 square feet for both lungs.



A Bronchial Tube bifurcating, and one of these branches again dividing. Air-cells, interlobular tissue, and pleura, also depicted.

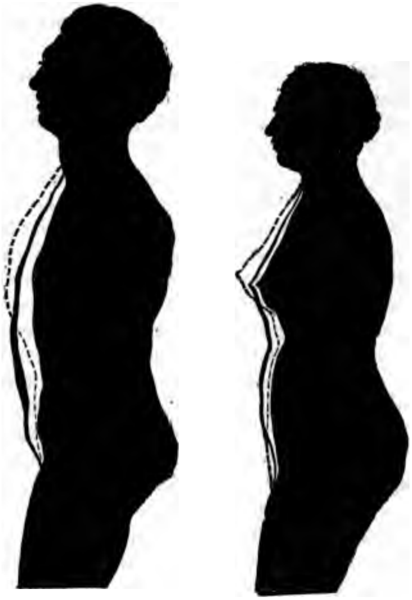
The septa are so thin that the capillaries project by nearly all their circumference into the cavity of the 2 cells. They may pierce the wall of the cell, and enter again on the opposite side. These minute vessels are figured on next page, and are best seen, by injecting size into the pulmonary artery when it passes into the capillaries, and by slicing when cold beautiful preparations are obtained. The capillaries are about $\frac{1}{180}$, and their walls, which alone separate the air and blood, $\frac{1}{2000}$ in thickness. Powdered charcoal, sulphur, mercury, and, according to some, pus-cells, are retained by them if introduced into the venous circulation. The bronchial arteries, according to *Waters*, merely nourish the larger bronchi and the parenchyma, the pulmonary artery supplying the true respiratory part of the lung.

Air Cells and Capillaries of Lung.

The movements of Respiration are divided into those of inspiration and expiration, and also into 1. Abdominal, where the diaphragm moves alternately upwards and downwards between the chest and abdomen. 2. Costo-inferior, where the lower ribs act; these occur in men, but, 3, Costo-superior, occurs in females, and produces the heaving of the chest. Respiratory movements are also classed, according to the power employed, into ordinary, forced, and extraordinary.

Inspiration is ordinarily produced by the action of the diaphragm. During expiration the muscle is very prominently convex towards the chest, and then descending, it approaches a plane, but never attains it; by this simple change great increase of capacity is produced, as the thorax is very wide below. In descending, it protrudes the viscera towards the muscular abdominal wall, which then re-acts during expiration. In animals which possess a diaphragm it is essential to their respiration, for if the phrenic nerves be divided, instant death occurs.

The intercostals were carefully studied by *Hamberger* (Physiologia Medica, 1751), who thus explained their mechanism: the ribs are parallel bars movably jointed to the fixed vertical spine and the sternum; the external intercostals, whose fibres slant downwards and forwards, raise and separate the ribs, pushing forward the sternum and increasing the thorax in the vertical and antero-posterior direction; the internal intercostals are antagonistic, as they slope upwards and forwards, and thus powerfully effect expiration. As disease may render useless some one part of the respiratory mechanism, it is an admirable provision that other parts may compensate. The following muscles are concerned in forced or extra-



Male and Female Figures, to show the portions of the Thoracico-Abdominal Cavity which move in ordinary (continuous line) and forced respiration (broken line).

ordinary inspiration in the order enumerated: levatores costarum, cervicalis ascendens, serratus posticus superior, and when the arm and neck are fixed, the serratus magnus, pectorales, subclavius, sterno mastoideus, trapezius, &c.

Expiration is due to the return of the diaphragm, ribs, and lungs, to the state they were in before inspiration. The lungs are also decidedly muscular, as *Williams* showed by stimulating those of a recently dead animal by galvanism, when the air forced out affected the flame of a candle. Dissection proves their muscularity and elasticity. The muscular tissue loses its irritability after repeated stimulus, and would seem to be in a spasmodic state in asthma; hence the beneficial effect of anti-spasmodics, above all, the datura tatula, in these cases. It serves more to regulate the amount of air to any part of the lung, as that of the arteries does with blood, than to be a usual expiratory force, as it would tend partly to drive the air back. It may expel mucus. Elasticity gives an expiratory force calculated by *Hutchinson* as 150 ℔ for the male, as the surface of the lungs are about 300 sq. inches; and 123½ for the female, the surface being equal to about 247 sq. inches.

The act of expiration is ⅓ more vigorous than that of inspiration, and will raise a column of mercury 10 inches, a force equivalent to over 1000 ℔, or nearly half a ton. This power diminishes according to height after 5 feet 8 inches, and increases enormously with athletic exercise. During attempted asphyxia the inspiratory power is so much increased, that a dog will raise mercury 4 inches—or if the head be plunged in that metal, it will be sucked into the minutest bronchial tubes.

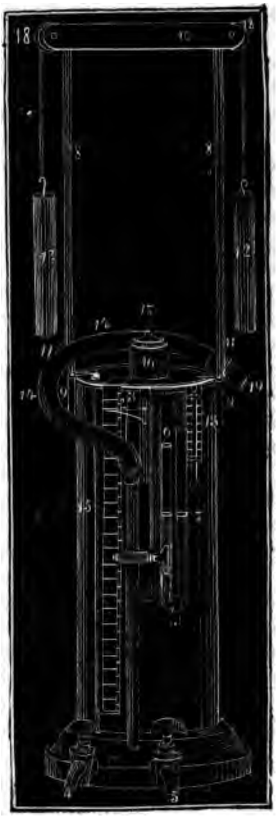
The respiratory movements fill the lungs much more perfectly than insufflation can, which is also apt to rupture the air-cells. When a wound in each pleura is produced larger than the diameter of the trachea, death occurs from compression of the lungs; any gradual pressure however on one is borne, as the other compensates. The rima glottidis is enlarged during inspiration by the crico-arytenoid muscles, and closed—often spasmodically, as in cough—during expiration. Stertor in coma and snoring in sleep are mainly due to the same closed condition.

Occasional Respiratory Acts are as follows:—Sighing is caused by the mental emotion abstracting attention from the breathing efforts, when more air is required, and admitted by a full inspiration. Yawning, in which inspiration is still deeper, is involuntary, and, as is well known, often imitative. Sobbing and hiccup are expirations with the glottis closed; laughing and crying, with it open. Coughing is a reflex movement excited by mucus, cold air, a morsel having "gone the wrong way," &c., and governed by the medulla oblongata: it is preceded by a full inspiration and closure of the glottis, which is then suddenly forced open. Sneezing is very similar, but the air shut from the mouth by the soft palate rushes through the nose to expel any irritant. It is in some persons reflex through the optic nerve as an excito-motor; *Müller* remarks, "I sneeze whenever the bright light of the sun falls on my eyes."

The number of Respirations is about 16 or 18 per minute, but if oneself endeavours to count them, they become more frequent by the attention to the act. Every 5th is more vigorous. They are in proportion to pulse as 1 to 4 or 5; but in the evening they increase, though the pulse decreases. In disease the ratio may be lowered, as to 1 to 8 in typhoid, and after narcotics; or they may even increase beyond the number of the pulse. Thus *Elliotson* relates a case of hysteria where the respirations were 106, pulse 104. The respiratory acts are automatic, occurring without our being aware of them, but excited by the un-ærated blood in the lungs, or perhaps encephalon. We cannot abstain from breathing for more than 20 or 30 seconds, when we are forced to inspire by most unpleasant and suffocating sensations. The pneumogastric, sympathetic, and trifacial are the excito-motor nerves; the medulla oblongata the centre, and the facial, spinal accessory, phrenic, posterior thoracic, and intercostal, the chief reflecto-motor nerves of respiration. *Sir C. Bell* grouped the last as the respiratory nerves, and tried to refer all their origin to "the respiratory tract," which he placed between the olivary and restiform bodies of the medulla, and the anterior and posterior roots of the ordinary spinal nerves. The first inspiration is excited by the cold air acting on trifacial nerve, and *Marshall Hall* relates that he has seen it delayed when the bed-clothes covered the face. It has been also attributed to the change of position of the viscera enlarging the chest, and by *Haller*, "forte et cibi desiderio quem amnii penu hauserit." It is sometimes prevented by slow parturition, constituting the "atelectasis pulmonum" of *Jörg*.

Division of the pneumogastric, or main excito-motor nerve, reduces the respirations to half their number, and makes them prolonged and laborious, the anmial sinking in some days from gradual asphyxia with congested lungs. Some of the muscles we have enumerated as respiratory may serve other purposes—thus, the serratus magnus, which, when scapula is fixed, is inspiratory, is used in moving the upper extremity when the chest is filled and the escape of air prevented. These facts were demonstrated on a dog who had the habit of leaping by the use of this muscle, for when the trachea was perforated he could not perform this action.

The amount of Air taken in at each ordinary inspiration is about 20 cubic inches, but has been estimated at 14 and 40. This quantity flowing in and out of the chest is termed the "tidal" or "breathing air;" that we admit above this, "complemental air," and which when expelled by next expiration is termed "supplemental." The amount which we can expire over this is termed "reserved air," and there still remains in the chest, "residual air," which no effort can expel. This is roughly estimated at 40 cubic inches, but, like the previous quantities, varies very much. The air which we can expel after the fullest inspiration is said to measure the "vital capacity" of the chest, to which must be added the amount of residual air, if the quantity of air which the chest will hold is required to be known. These terms have been applied by *Jeffreys* and *Hutchinson,* the latter of whom has invented the spirometer, an instrument like a gas-holder, consisting of two cylinders, one containing water and the other inverted within it, and into which the air is blown through a tube. A small dry gas-meter makes a cheaper and more accurate spirometer. It determines the vital capacity of the chest, the average of which is 240 cubic inches for men, and scarcely more than half that for women, according to *Bourgery.* It is influenced almost alone by height, for corpulency without height decreases it. The vital capacity increases 8 cubic inches for every inch in height, from 5 to 6 feet.



Hutchinson's Spirometer.

The Inca Indians, breathing such rare air so high above the sea-level, have an enormous vital capacity. *Hutchinson* found the maximum to be 464 C. I. in a man 7 feet high, and 308℔ in weight; the minimum, 46 C. I., in Don Francisco, the dwarf, whose height was 29 inches, and weight 40℔. Any wide departure from the standard is suspicious of pulmonary disease, or of some abdominal tumour pressing on the chest, and thus the spirometer is of use in examining lives for insurance.

The number of respirations, and quantity of air inspired at each, varying so much, the diurnal amount must also vary; but in the construction of barracks, hospitals, &c., from 600 to 1,200 cubic feet of air space is regarded as a sufficient quantity for each person. Of such hygienic principles I have said much in another work. The average vital capacity for a man 5 feet 8 inches high being 240, it will take 12 inspirations at 20 cubic inches each to change the whole of the air in the lungs. During a year about 9,000,000 respirations occur, consuming about 100,000 cubic feet of air, and arterializing about 3,500 tons of blood. The amount of air inspired is very much lessened by tight-lacing, which sadly interferes with the breathing apparatus. Even man's dress may prevent the full inspiratory action, as a man who can inhale 190 cubic inches when naked, can inspire but 130 when dressed.

Researches on the mechanism of respiration, and the interchange of gases in the lungs, have still to be considered, and afford admirable examples of the application of the principles of physics to physiology. *Dalton* discovered that if a light gas be placed above a heavy one, it will sink and the heavy one rise, the particles of each finding space between those of the other. This "diffusion of gases" occurs, then, in opposition to gravitation. *Graham* further demonstrated, that through porous substances gases, if dry and chemically indifferent, will diffuse in inverse proportion to the square roots of their densities. Animal membranes, films of india-rubber, shellac, soap bubbles, are media which permit diffusion. *Draper* has shown that a gas held in solution will diffuse with another free, or two gases will diffuse through a liquid although this has no pores—but they will not then obey *Graham's* law. It will be seen that these principles explain the interchange of the fresh and the deoxygenated air in the tubes and air-cells, the passage of oxygen to the blood, and of carbonic acid out of the blood, and also the exchange of these gases in aquatic respiration. The sugar brought so plentifully to the lungs, besides chemical functions, may promote osmose; water-breathing animals die at once if placed in solution of sugar.

The diffusion quantities of oxygen and carbonic acid are respectively 1,174 and 1,000, and it was supposed that respiration mainly depends on the interchange which these would produce, but the changes during the process are far more complex. The volume of expired air is greater than that of inspired in the ratio of 99·5 to 97·2, which is due to its containing more watery vapor and being more rarified by heat. If the water be removed, and the temperature reduced, the volume of the expired air is less than that of inspired according to the loss of oxygen, for carbonic acid has only the same volume as that of the oxygen in it.

The Chemical Phenomena of respiration will be best understood by considering the changes the air undergoes, and we will therefore first study the average composition of pure atmospheric air, which, excluding mechanical impurities—as particles of dust, sporules of plants, animal matters, and the gases emitted from factories—is remarkably uniform; so that the different effects of the bracing country air and that of the close city were for a long time unexplained. In my "Lectures on Public Health," I have drawn attention to gaseous and suspended organic impurities in the air, the ill effects they were capable of producing, and the means by which they may be each detected and remedied. The composition of atmospheric air, when filtered from suspended particles of animal debris and other organic matters which the cilia probably reject, is as follows:

	Oxygen	20·61
	Nitrogen	77·95
	Carbonic acid	·04
	Aqueous vapour	1·40
	Ozone	traces
	Ammonia	
	Nitric acid	
	Carbonetted hydrogen	
In towns	Sulphuretted hydrogen	
	Sulphurous acid	

Such air by respiration becomes (1) warmed; (2) deoxygenated; (3) charged with carbonic acid; and (4) with water.

1. It usually approaches blood-heat—more or less according to the time it remains in the lungs, and will thus be warmer than the surrounding air, save in very hot climates.

2. **The amount of Oxygen** taken from the air has been calculated at about 4 per cent., and a corresponding amount of carbonic acid is given in exchange. The oxygen enters into association with the red-cells, which carry it all over the body, as there is no tissue which does not require it for the removal of effete matter, or as its proper excitant. Muscle, for instance, as *Liebig* has proved, will absorb oxygen and emit carbonic acid as long as irritability remains, and although deprived of blood. Insects have no true blood, yet perform the interchange in their tissues.

The Theory of Respiration propounded by *Liebig* was, that the venous blood contained carbonic acid as a carbonate of protoxide of iron, and gave it off in the lungs, where, taking more oxygen, the iron became a peroxide.

Ellis believed the venous blood to contain a hydrocarbon, which the oxygen in the lungs converted into carbonic acid and water. *Verdeil* stated that the evolution of carbonic acid was due to a peculiar acid he described in lung tissue, "the pulmonic," which decomposed the bicarbonate of soda of venous blood. *Bernard* finds that injection of solution of this salt into the jugular vein kills the animal by the evolution of carbonic acid. Exposure to a rare atmosphere causes the bicarbonate to give off carbonic acid. The theory of respiration suggested in 1791 by *Lagrange* and *Hassenfratz*, and supported by *Magnus*—who has discovered carbonic acid in venous, and oxygen in arterial blood—is, that the oxygen taken in uncombined by the arterial blood, converts the effete products throughout the whole system into carbonic acid, which, returned by the venous blood, is expired from the lungs.

3. **The amount of Carbonic Acid** varies very much, 4 per cent. of the air expired being a fair average quantity, and will be equivalent to 160 grs. of carbon per hour, or 3,840 grs. (8 ozs. troy) in the 24 hours. *Dr. E. Smith* found he expired 24·274 ozs. of carbonic acid, and *Dr. Frankland* 16·42. The amount evolved is influenced by the following circumstances :

INCREASED	DECREASED
By low temperature.	By high temperature.
,, neuro-muscular power.	,, debility.
,, food.	,, starvation.
,, skin diseases.	,, typhus and chronic lung diseases.
,, exertion.	,, repose.
,, wakeful state.	,, sleep.
	,, alcohol, tea, &c.
Up to 30 years age.	After 45.
In male.	In female, especially during menstruation.
To a maximum at noon.	To a minimum at midnight.
,, ,, in spring.	,, ,, in autumn.

As regards the influence of stimulant drinks, the experiments of *Dr. E. Smith* show results which are hard to reconcile. He found brandy, whiskey, and gin lessened the production of carbonic acid; rum, ale, porter, tea, coffee, and cocoa increased it, a result quite opposed to the statements of *Prout* and *Böcker*. He proves that more carbonic acid is evolved in a moist air; and as this is a measure of the waste of tissue, it shows the hygienic value of a dry climate. Cod liver oil lowers respiratory waste—hence partly its efficacy in phthisis; though, if tubercle consists of unoxidised carbon, as contended for by *Dr. MacCormac* of Belfast, matters which increase the amount of carbonic acid would be more suitable. Inhalation of chloroform remarkably decreases the evolution of carbonic acid, and that agent owes its efficacy as an anæsthetic to its not being combustible in the blood.

4. **The amount of Watery Vapour** is between 16 and 20 ozs. in the 24 hours, as determined by the well-known experiments of *Lavoisier* and *Seguin*, which also show its proportion to cutaneous transpiration. They enclosed the body in an air-tight bag, and breathed into a vessel. The amount of water thus collected was equivalent to 18 grs. per minute, of which 11 came from skin, 7 from lungs. The water is partly derived from the blood by exhalation and partly produced by the oxidation of the hydrogen in food and tissues. It holds dissolved carbonic acid—the amount of which has not been duly accounted in determining its evolution from the lungs—and a peculiar animal matter, probably albuminous, and similar in odour to the skin and blood. This fetid matter is much increased by indigestion, when some unassimilated substances are got rid of by the lungs. Odorous matters, as camphor, alcohol, turpentine, rapidly appear in the breath if swallowed, or may by inhalation be introduced into the system.

Nitrogen in air acts merely as a diluent, and according to *Boussingault*, is given off into expired air more frequently than absorbed.

Ammonia is also expired, as proved by breathing on a microscope glass which is exposed to the vapour of hydrochloric acid, when crystals may be obtained, and common salt and urates may be found in the pulmonary exhalation.

Asphyxia is the term by which the cessation of respiration is usually denoted, but apnœa is a more correct expression. It may result from the introduction of some gas not containing oxygen, which we have seen is essential to respiration, or from the exclusion of atmospheric air, as in drowning or suffocation. Gases are either respirable or irrespirable. The former may be noxious from excess of oxygen, from want of it, or from containing some positively injurious agent. The latter prove fatal in the same way as a mechanical obstruction, for the glottis spasmodically closes and excludes them: if in small quantity they merely excite coughing.

The chief examples of these classes of gases are here tabulated:

I. **Respirable** gases, injurious by

EXCESS.	DEFICIENCY.	POISONOUS QUALITY.
Oxygen,	Nitrogen,	Carbonetted hydrogen,
Nitrous oxide.	Hydrogen.	Phosphuretted hydrogen,
		Sulphuretted hydrogen,
		Arseniuretted hydrogen,
		Kakodyl,
		Cyanogen,
		Carbonic oxide,
		Carbonic acid.

II. **Irrespirable gases**:

Nitrous acid,
Chlorine,
Fluosilicic acid,
Ammonia.

When animals are made to respire pure oxygen their blood becomes of a bright scarlet, all the functions are excited, but stupefaction ensues from the great production of carbonic acid. *Sir H. Davy* discovered that nitrous oxide can be breathed for some time. It excites the nervous system, producing slight delirium and often laughter (hence its popular name of "laughing gas"), and if longer continued stupefaction or syncope follow. *Zimmerman* found that animals evolved ⅓ more carbonic acid when breathing this gas. Hydrogen, like nitrogen, if pure, is not in itself injurious, for if oxygen be mixed with it, animals breathe the mixture with impunity. Carbonic acid is usually supposed to produce a dark colour of the blood, and carbonic oxide a precisely opposite effect. These two gases are generated by the burning of charcoal, which is a common mode of suicide in Paris. That carbonic acid is really poisonous was shown by *Rolando*. He tied one bronchus in a land tortoise and the animal survived; but when he passed carbonic acid through one, and allowed the other to inspire air, death soon occurred. Arsenical gases are the most intensely poisonous, an almost inappreciable quantity having destroyed the life of Mr. Brittain, a chemist in this city some years ago.

When atmospheric air is excluded from the lungs, the movement of the blood in their capillaries almost immediately stops, and the right side of the heart and whole venous system become loaded with blood. The blood on the left side of the heart and arteries is scanty, and remains unarterialised. *Prof. Draper*, as before-mentioned, regards the interchange of gases in the lung as the main cause of the circulation, and thus stagnation must occur if such interchange be prevented; but circulation can again go on if air—or, still better, oxygen—be admitted. A stream of carbonic acid directed on the capillaries in the web of the frog's foot will stagnate the blood-cells within them. This effect, and their incapability of passing through the pulmonary capillaries, is probably due to the increase of size which that gas produces. *Erichsen* performed the following experiment, to show that some blood will still flow through the lungs from which air is excluded if the action of the heart be kept up. He pithed dogs, kept up artificial respiration in the left lung, but tied the right bronchus; he found that as long as the heart beat, some dark blood flowed from the right pulmonary veins, and scarlet blood freely from the left. Another of his experiments went to prove that asphyxia does not depend on the passage of venous blood through the nervous centre, as he found animals died in the usual time although arterial blood was made to flow freely through them. *Ackermann* also has observed the condition of the brain during asphyxia, by trephining and inserting a glass plate into the aperture; he asserts that there is always remarkable anemia. It may be objected that the cranial vessels are always found full after death, but gravitation of the blood which remains fluid would account for this. Animals will live longer if merely deprived of air than if they are submerged in water; thus, drowning kills by the absence of air, the poisonous effects of the retained carbonic acid, and the entrance of water into the respiratory passages.

A committee of the Royal Medical and Chirurgical Society, which investigated this subject some months ago, found that dogs were deprived of life by being kept under water for 1½ minutes. When simply deprived of air, as by plugging the trachea, respiratory movements continued for 4 min. 5 sec., and the heart continued to beat for 7 min. 11 sec., or 3 min. 6 sec. after all respiratory efforts had ceased. Rabbits afforded a complete exception to the latter fact. Dogs will recover by themselves after air has been excluded for 3 min. and 50 sec. The rapidity of death by drowning is owing mainly to the entrance of water into the lungs, and if the inspiratory efforts are enfeebled by intoxication, narcotic poisoning &c., life may be prolonged considerably. The same committee investigated the respective merits of the *Marshall Hall* and *Silvester* methods for restoring persons drowned. The former, termed "the ready method," consists in rolling the body alternately from the front to the side and back again, so as to compress the thorax and allow it to expand again. It was found that never more than 15 cubic inches of air could be thus introduced into the lungs of a dead subject. *Dr. Silvester's* plan is to alternately raise and depress the arms, and thus expand and contract the capacity of the chest. As 44 cubic inches can be thus sucked in, and as the warm bath can be employed at the same time, it seems the most trustworthy.

Animal Heat.— Organic bodies are warmed directly by the sun's rays to a degree varying with the diurnal rotation of the earth, producing day and night, and with the earth's course round the sun, producing the change of seasons. Heat is also radiated from the earth, where it is either stored up from the sun's rays or generated in the interior. But animals, and man above all, are independent of these influences, for they can produce a temperature far more equable within themselves. Man's temperature averages about 100° Fahrenheit, or according to *Brown-Sequard* 103°, being somewhat higher in such internal parts as the rectum and vagina, and gradually lower as we proceed towards parts farther from the centre of the body. *Dr. John Davy* found it but 90° at the sole of the foot. *Becquerel* and *Breschet* showed the deeper parts had the highest temperature, by inserting wires connected with a thermo-electric apparatus; thus while the heat was 98° at 1¼ inches from the surface, it was but 94° at ⅓ inch. They found muscle the warmest tissue, especially during contraction, when it was raised 2 or 3 degrees.

Disease alters the temperature considerably: thus, in scarlatina and fever it has attained 107°, in tetanus 110·75°, and in phthisis and pneumonia, owing to the diminished oxidation in the lungs, the skin acquires a great increase of heat. All practical physicians must have felt the "calor mordax" of acute pneumonia. In Asiatic cholera and morbus cæruleus the temperature may be as low as 77° in the mouth.

The mean temperatures of some animals are stated in the following table:

Swallow ...	111·25	Man ...	100
Bat ...	105·50	Ape ...	95·9
Squirrel ...	105	Carp ...	51·25
Seal & Whale	104	Toad ...	51·6

It is remarkable that all animals are exceeded by a plant, the arum cordifolium, which during its inflorescence has attained, in air at 66°, the enormous heat of 121°. The temperature of many animals varies much with the medium in which they live, most reptiles and fish being but a degree or two above the temperature of air or water. *Humboldt* has seen fish thrown alive from volcanoes in water at 210°. Heat is generated by even the humblest invertebrates, for if water containing infusoria be frozen under the microscope, each animalcule will for a long time keep a space of water about it. This may be due to ciliary motion.

It is astonishing what variations of temperature man will bear. Arctic voyagers, *Parry*, *Back*, and recently our illustrious countryman, *Sir Leopold M'Clintock*, have borne very low temperatures without much inconvenience if the air was still; but wind, by constantly substituting a fresh, cold atmosphere for that which the body had heated, was intolerable. Cold can be produced artificially as low as —166°, and the greatest natural cold ever observed was in 55° N. lat., where the thermometer fell to 91·75° below zero; while in India the temperature is often 110°. So that man can preserve a uniform temperature in a medium varying through a range of over 200°. Under such variations of external temperature, that of the body remains nearly uniform, for it is found that animals perish if their temperature is raised 11° above the normal standard.

Hybernation is a condition of torpidity which low temperatures will produce in some animals—for instance, the marmot, hamster, dormouse, beaver, hedgehog, bat, &c., which being mostly insectivorous, would perish from want of food were it not for this admirable provision. Artificial hybernation may be produced in summer by cold. The bat, which of all mammals has the highest temperature, becomes reduced in the torpid state to a few degrees above the surrounding air, and its pulse falls from 200 to 28 per minute. In the marmot the pulse falls from 150 to 15 per minute, and the number of respirations from 8 per minute to 1 every 4 or 5 minutes. But $\frac{1}{30}$ the former amount of oxygen is consumed.

That some fuel is, however, consumed is shown by the formation of a fatty mass, probably the thymus, in the anterior mediastinum before hybernation, and the enormous reduction of fat after being some months dormant, even to the amount of $\frac{1}{100}$ of its former quantity. Strangely enough, however, the animal at first gains weight by absorbing oxygen, which is then discharged as water by the kidneys. They can bear conditions which would rapidly asphyxiate them in the wakeful state. Thus a hedgehog may be kept 22½ minutes under water, and *Spallanzani* kept a marmot for 4 hours in carbonic acid, without injury. It may be noted as a curious anatomical fact, the reason of which is unknown, that an artery similar to the internal carotid passes through the stapes of many hybernating animals, and that the cœcum is usually absent.

Calorific Power does not seem fully developed in young animals, as *Edwards* has proved that they are easily killed by deprivation of artificial heat. This suggestive practical fact may be perhaps accounted for by the nature of their food. Premature children especially require artificial warmth. In ascending high mountains men are chilled to the bones, and this is due to the rarity of the air and consequent insufficiency of oxygen, as well as the low temperature at such altitudes. For the same reason they suffer from muscular inactivity. Such effects are not produced by descending in diving-bells, notwithstanding the decreasing temperature, as the air is condensed and the supply of oxygen abundant.

The Cause of Animal Heat is oxidation of the tissues and food, and is therefore identical with combustion, as shown by *Lavoisier*. The fuel consists mainly of carbon, hydrogen, sulphur, and phosphorus, and is supplied both by the tissues, which perish the moment they perform their function, and by such food as fat, sugar, and starch, which abound in carbon and hydrogen. It is calculated that the amount of caloric generated by man in 24 hours would raise 6 gallons or 60℔ of water from 32° to 212°, which affords the most convenient measure of heat. That this great amount would be produced by the combustion of as much carbon as is expired in the form of carbonic acid, experiments have disproved, and the rest of the oxygen inspired is used in converting hydrogen into water, which the lungs exhale, and in producing sulphuric and phosphoric acids from sulphur and phosphorus. These acids combined with bases are excreted by the kidney. Ordinary oxygen would not combine with hydrogen (flame or electric spark being usually required to unite them) or with carbon, sulphur, or phosphorus, with sufficient energy or rapidity, and it is probably condensed into the liquid state with the red-cells of the blood, or in some allotropic form—perhaps ozone. The cold, and want of neuro-muscular power in ascending into an elevated atmosphere where fires will scarcely burn, shows how dependent we are on a due amount of oxygen.

The entire amount of heat liberated cannot be accounted for by oxidation, and other chemical, electrical, and perhaps such mechanical actions as friction, are supposed to contribute to its production. The conversion of fluid blood into solid tissues must also set free heat. Heat is said to be highest in plants when they are absorbing carbonic acid and emitting oxygen, but during germination and flowering, carbonic acid is produced and great heat is developed.

Food is believed by *Liebig* to afford the heat of the body by direct oxidation of its hydro-carbonaceous constituents, and 87 per cent. of that generated by herbivora, and 78 in carnivora, can be so accounted for. The character of food is much influenced by climate; in cold countries fats and carbo-hydrates must be supplied, and the Laplander is instinctively prompted to regard the filthiest oils his choicest luxury. *Chossat's* experiments on starvation, which have been before alluded to, showed that cold constantly occurred when food was withheld, and that the fat, muscles, and, lastly, nervous matter gave way to combustion. Fat animals will bear starvation much longer than lean ones. A fat pig lived 160 days without food, being confined by a chalk bank, but lost over 120℔ in weight. The amount of heat produced is then very nearly proportional to the quantity of carbonic acid evolved, and the circumstances under which this varies have been referred to at p. 163. The amount of oxygen absorbed by plants in germination and flowering is enormous. The sexual organs of the arum have been found to take in 132 times their volume of the gas in 24 hours.

The skin is to a certain extent a respiratory and heat-producing organ, and between $\frac{1}{30}$ and $\frac{1}{60}$ as much carbonic acid is emitted by it as by the lungs. The bubbles which rise from a limb placed in water are composed of this gas, as shown by using lime-water. The moist skin of amphibia has much greater aërating power, and the frog still lives when the mouth is closed entirely. They will live under water if its temperature be under 48°; if higher, their tissue-waste is greater, and they must have aerial respiration. *Becquerel* and *Breschet's* experiments show that even in mammals the heating power of the skin is necessary to life, for by shaving and varnishing rabbits they found the animals rapidly cooled and died. Before leaving this part of the subject two theories, which for a long time gained credit, may be noted: *Dr. Black*, the discoverer of carbonic acid, supposed that all the combustion, and therefore all animal heat, was produced in the lungs. The evident objection to this view, that the lungs would be the only part heated, was attempted to be explained away by *Crawford's* theory: he supposed that the heat was rendered latent by the arterial blood, which had a greater capacity than venous, and was thus distributed through the body.

The influence of the Nervous System on animal heat is so great that *Sir B. Brodie* concluded it was entirely so produced. He pithed animals—that is, removed their cerebro-spinal axis—and kept up artificial respiration, yet the animals cooled. He introduced air too quickly—for others, by causing only 12 respirations per minute, have obtained opposite results. *De La Rive* supposes that the sympathetic and cerebro-spinal systems are as negative and positive poles, and so evolve heat. *Bernard* has shown that the section of the sympathetic in the neck immediately and permanently increases the temperature on that side of the neck and face by 11°, or even more. This elevation disappears if a galvanic current be applied to the upper segment, and recurs if it be removed. Chloroform acts similarly. The progress of inflammation is much more rapid on the injured side. The same section dilates the vessels as those of conjunctiva, but such afflux of blood is not the cause of the increased heat, as it takes place even when the vessels are tied. The increase is probably due to greater oxidation of the tissues, now no longer protected by nervous influence; and perhaps, too, the supply of nutritive matter is also burned off, as it cannot be appropriated, innervation being essential to nutrition. *Bernard* states that division of a sensitive or motor nerve is followed by decrease of heat. Although sudden injury to the nervous system may temporarily heighten the temperature, paralyzed parts are invariably lower, as proved by *Dunglison* and by *Earle*, who found a difference of 22°, which was lessened 7° by an electric current. Those remarkable cases of great elevation of temperature after death by cholera and yellow fever, prove the influence of the nervous system not to be essential. The increase occurred between the periods of somatic and molecular death. The nervous system then can control, though it does not generate heat—just, as *Draper* remarks, the engineer of the locomotive can regulate, though he cannot produce heat; and if he be removed, or the nerves divided, all regulation of temperature ceases. Nervous influence may prevent the indiscriminate removal of all particles the destroying oxygen meets with. *Draper* appeals to the following facts in physics as showing a similar controlling action:—if a plate of zinc and one of copper be kept apart in acidulated water, no voltaic action goes on, but at once occurs if they are connected by a conducting wire. Newly made lamp-black will ignite spontaneously on exposure to air; whereas diamond, chemically identical, but allotropic, is quite unchangeable. There may be allotropism of organic bodies under the control of the nervous system.

Cooling Influences are, of course, necessary to preserve the uniform temperature of the human body. Heat is lost (1) by radiation from the skin and its contact with air, from 30 to 50 degrees colder at least in our climate than the body. Man's reason has taught him to regulate this by placing bad conductors, as warm clothing, on his surface; (2) by evaporation, there being lost by cutaneous and pulmonary surfaces some 3 or 4 ℔ of water daily; this powerful cooling agency, however, varies much with the hygrometric state of the atmosphere. The dark surface of the negro absorbs the heating rays of the sun, and thus, by great evaporation, can sustain a climate intolerable to others. The lady's fan does not propel colder air against the face, but merely promotes evaporation by fresh portions of air. *Chabert*, "the fire-king," *Blagden*, and the workmen of *Sir F. Chantrey*, the sculptor, have borne extraordinary temperatures, the former having entered a chamber of which the temperature was between 400° and 600°. The air should be dry, for if moist, no evaporation was allowed, and such heat was intolerable. The hand, if damp, may be put into molten metals, for a layer of spheroidal particles of water intervenes, and prevents any great rise of temperature. 3. The air we breathe abstracts heat from the nasal bronchial and pulmonary surfaces, and thus affords another cooling agency, having the advantage of raising the temperature of the air to a degree which will not chill the pulmonary capillaries. When cold air is admitted by an opening in the trachea, made suicidally or by the operative surgeon, fatal bronchitis is often excited. The fatality of the same disease in infancy and old age, when calorific power is not energetic, is well known.

Light is another physical agent which is believed to influence the development and other nutritive changes of animals. It was asserted in 1824 by *W. F. Edwards*, that the tadpole, if deprived of light, did not become developed into the perfect frog. This statement, however, cannot be now accepted as true, as *Mr. Higginbotham* and *Dr. R. M'Donnell* have conducted some most interesting experiments, which prove that the arrest of developmental change is due to the low temperature and absence of oxygen and proper vegetable and animal food, rather than to the denial of light. The latter has discussed the whole subject in an able paper in "Le Journal de la Physiologie, No. d'Octobre, 1859." Elevation of temperature hastens the metamorphosis, and in this way the heating rays of the sun may have some slight influence. In the same memoir he also shows the homology of the swimming bladder of fishes to the lungs of higher vertebrates. The pigmentary matter of the blood and of tissues, which is probably derived from it, is not fully developed in man or animals deprived of light; but as in such cases there is usually also a deficiency of oxygen, the effect may be due to the latter agent. Darkness is usually considered to be favourable to the fattening of cattle and geese, as seen in the cruel expedient they adopt in Strasburg to increase the bird's liver, for making the "*patie de foie gras.*" Other animals, however, seem induced to eat excessively if strong light is made to alternate with darkness; and the manner in which Italian gourmands employ this principle for the fattening of ortolans, is amusingly narrated in the work on Italy of our brilliant countryman, the Right Hon. Mr. Whiteside.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Describe the structure of the trachea?
2. What muscles produce inspiration? and describe the action of three of the most efficient.
3. What terms have been applied to the quantities of air which can be expelled from the lungs by various degrees of force?
4. State the components of ordinary air, and the purpose of its most important elements.
5. Describe the ways in which various modes of suffocation produce death.
6. What animals undergo hybernation, and what are its phenomena?
7. How is heat generated, and how regulated in the human body, especially when it is exposed to excessive temperatures?

SENIOR.

1. Describe the ultimate terminations of a bronchial tube.
2. Explain physiologically sighing, coughing, and sneezing.
3. What changes does air undergo by respiration, and offer proofs to show where its constituents suffer chemical action.
4. Arrange in parrallel columns the circumstances which increase or decrease the evolution of carbonic acid by the lungs.
5. Give some examples of variations of external temperature, and the effects of disease on the temperature of the human body.
6. What are the other decarbonizing surfaces besides the lungs?
7. What effects have light been supposed to produce on animals, and how have the results been shown to be fallacious?

SECRETION.

Secretion is that process by which matters are separated from the blood, and such products are either excrementitious or useless, recrementitious or useful The former are often termed excretions. Like the analogous act of nutrition, the appropriation of the special material is effected by cells lining the interior of each special gland, which drains its peculiar secretion from the blood, and their very great variety illustrates the very complex nature of that fluid. Some fluids which merely ooze through the coats of the capillaries, are termed exudations or exhalations, but there are no special "exhalents" as once believed. The retention of the materials of the excretions is injurious, or will even destroy life, as when the kidney is removed from animals. The chief excretions are water and carbonic acid from the lungs and skin, urea and other nitrogenized substances from the kidney, lactic acid and various salts from the skin and kidney, and many matters discharged from the liver and other alimentary glands with the fæces. The excretions thus afford examples of the gaseous, liquid, and solid states.

The most remarkable recrementitious products are, saliva, gastric and pancreatic juices, some elements of bile, the cutaneous secretions, and those connected with reproduction, as semen, milk, &c. One fluid may contain both recrementitious and excrementitious materials—for instance, the bile; or as regards its composition may be excrementitious, yet in being discharged may fulfil a useful purpose—as sweat, which cools the body by its evaporation.

One gland by increased activity may compensate for the secretion of another being checked—and this is termed "vicarious secretion." It shows that special cells are not required to separate each material, for we find urea, cholesterin, and other matters which exist preformed in the blood, in many various secretions. There are, however, other substances which can be only generated in each special gland out of elements afforded by the blood. Many substances, as ferrocyanide of potassium, lactate of iron, sugar, &c., show a preference for some glands, either not passing, or passing very slowly, through others; and much the same might be said of various kinds of membrane in regard to dialysis through them. Uniformity of structure and development, as inflections from the skin or mucous membrane, indicate probably similarity of function, and suggest that vicarious secretion may take place. The best example of this occurrence is afforded by *Dr. Laycock's* cases, amounting to 124, where urine was discharged from

	Navel.	Stomach.	Bowels.	Skin.
in	34	33	20	17

Salivary glands.	Mammæ.	Eyes.	Ears.	Nose.
5	4	4	4	3

What are termed conglobate glands are merely convoluted tubes communicating with each other. Such are the lymph and ductless glands; and as they have no excretory duct, they must pour their products into the circulating current. Conglomerate glands are inflections from the skin or mucous surface, much branched and lined by the globular form of epithelium, which selects the materials of the secretion proper to each gland. These cells develop from the granular state, and when filled with the secretion burst into the excretory duct. The parotid, the structure of which is represented at p. 71, is a good example of the conglomerate gland. Many physiologists attach importance to the size of the capillaries of each gland, as they think the straining off of each special matter can be thus accounted for. The duct is often muscular, may be distended into a temporary reservoir, and is usually single; those of breast, lacrymal, tonsil, sublingual, and prostate, are multiple. Exhalations, which mainly occur from serous surfaces, will be hereafter considered; but it may be here stated that, according to *Schmidt*, their composition varies with the size of the capillaries and quantity of albumen in the blood. The quantity of albumen in some of these fluids is as follows: pleural, 2·85; peritoneal, 1·18; arachnoid, 0·6; areolar tissue, 0·3, in the hundred parts.

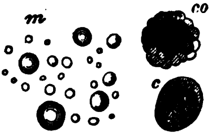
The nervous system powerfully influences secretion. Both motor and sympathetic filaments can be traced into glands. The motor seems to increase the flow of blood, and thus renders the secretion more abundant; the sympathetic, by constringing the vessels, diminishes the secretion remarkably. The secretion of urine in an hysterical paroxysm, the flow of bile and subsequent diarrhœa by terror, the gush of tears which grief excites, and the production of milk by a mother while in a fit of anger, so hurtful as to poison her offspring, are instances of the influence of innervation on the function of secretion. It has been found that division of the nerves of the kidney which surround the renal artery, produces either suppression of urine or the secretion of a bloody coagulable fluid. We have before mentioned that *Bernard* discovered that the blood in the veins coming from a gland was scarlet, if the gland was secreting; modena, from being charged with carbonaceous matter, if inactive; and precisely the contrary is the case with muscles.

Many secretions have been already, or will be subsequently described, in treating of the function which they subserve; but in the present chapter we will consider milk, as being entirely recrementitious; bile, which is partly so; and urine, which is wholly excrementitious.

THE MAMMARY GLAND

Consists of tubes, which can be traced from the nipple, where they open by about 20 orifices. At about the areola they dilate into "ampullæ," which in woman hold about a drachm; in cows, constituting the udder, about a quart. The lactiferous ducts then branch into lobules bound together by areolar tissue, and end in cœca, or follicles about $\frac{1}{200}$ in diameter. These are lined by epithelium, and are filled with oil-cells during lactation. Amidst the follicles, blood-vessels, lymphatics, and nerves plentifully ramify. The gland is developed, like the sebaceous glands, as an infolding of the skin, and it begins to branch into lobules about the sixth month of intra-uterine life. The male breast remains in a rudimentary condition usually, but *Humboldt* and others have recorded instances in which milk was secreted by men. *Dr. Davys*, of Swords, has met with a case (which he has kindly shown me) where the left gland was as large in a healthy man 37 years of age as it usually is in women not suckling. The organ appeared so perfectly formed that it might have secreted milk if excited by the application of a child. The breasts of infants, male as often as female, occasionally secrete a fluid identical with milk. Abnormalities may occur with regard to the number of breasts, as in *Dr. Shannon's* remarkable case, where there were four, all secreting milk; but entire absence of the mammæ is extremely rare. The nipple is surrounded by the areola, which undergoes definite changes during pregnancy, and possesses muscular tissue, like the ducts, which can alter its direction. In early life it is conical, but after suckling the extremity becomes much enlarged, so that the infant may grasp it more readily. The changes produced by age are described by *Sir A. Cooper*: "At 16 years, it is slightly wrinkled; at 17, it has small papillæ on its surface; from 20 to 40 years, the papillæ are larger; from 40 to 50, the nipple becomes wrinkled; from 50 to 60, the nipple is elongated; and in old age it usually has a warty appearance.

The Milk, secreted after parturition, is called colostrum, and in it can be seen very large fat-cells, discovered by *Donnè*. It has usually a purgative effect on the infant. After two or three days, milk assumes its familiar characters of whiteness and opacity, due to minutely divided fat-cells, sweetish taste, and peculiar odour, stronger while warm. Its specific gravity averages 1·032. It has an alkaline re-action, save in the carnivora. When left still for about six hours, the fat-cells rise to the surface in the form of cream. Each cell has a wall of casein, so that ether will not dissolve out the fat; but, by dissolving this cell-wall by an alkali, or bursting it by churning, the fat can be separated as butter. The casein can be removed from the remaining fluid by acids or rennet, but not by mere heat. The following analyses indicate the composition of milk from two women 22 years of age, and similarly circumstanced as regards time of delivery, diet, &c., only differing in complexion :



Globules of Colostrum and Milk.

	BLONDE.	BRUNETTE.
Water...........	892·00	853·30
Butter...........	35·50	54·80
Casein...........	10·00	16·00
Sugar............	58·50	71·20
Salts.............	4·00	4·50

The proportion of these constituents vary very much throughout lactation, according as the respiratory, plastic, or saline ingredients are required for infant growth. It would appear that there is no casein whatever in colostrum, but instead of it albumen, for it is coagulated by boiling. In about 36 hours, or much less when the weather is warm or the air charged with electricity, casein acts as a catalytic, and changes sugar into lactic acid ($C_{24}\ H_{24}\ O_{24} = 4\ (HO,\ C_5\ H_5\ O_5)$), which then curdles the milk. The butyrin also throws off butyric acid, which produces the rancid smell. A pure, watery solution of milk sugar will never turn sour, and as it does not undergo alcoholic fermentation at the temperature of the body, no carbonic acid, which would distend the infant's bowels, is produced. Kiestin, which is found in the urine of pregnant women, or when lactation is checked, is composed of casein, butyric acid, and the phosphates.

The mammary gland, by a kind of straining, passes through some salts, refuses others. Thus, iodide of potassium if administered can be found in the mother's milk and infant's urine, which is not the case with ferrocyanide of potassium. Gold has been stained with mercury if placed in milk from a woman taking that drug. Quinine is one of the few vegetable substances which pass into milk; yellow, blue, and red tints are occasionally given to it by peculiar fungi. Like other secretions, milk becomes very concentrated during acute inflammations. In phthisis, the water is said to be increased, and the butter decreased to one-third. Blood, pus, and colostrum cells, long after parturition, may occur abnormally. The diurnal quantity of milk secreted by a suckling woman varies much, but averages about 40 ozs. The milk of cows and other animals differs so widely from human milk, and even that of other women so much from that of the mother, and artificial aliments afford so poor a substitute, that we cannot avoid deploring how often previous disease of the mother or the follies of fashionable life deprive the infant of the food designed by nature for it. Such circumstances are prolific causes of that widespread evil—infant mortality. The best substitute for human milk is recommended to be made as follows: Cow's milk, 8 ozs.; cream, 2 ozs.; water, 6 ozs.; sugar of milk, ½ oz. (For some remarks on this subject, see my "Lectures on Public Health.")

THE LIVER.

The liver is remarkable for its size, being the largest gland in the body, for occurring almost universally in lower animals, for intricacy of structure, and for the variety of functions it performs. It weighs about 4℔, or about 1/36 of the weight of the body, its proportion being very much greater in fœtal life, when also the left lobe is larger than the right. These differences can be accounted for by the circulation through the umbilical vein, here sketched, the course of which is as follows:

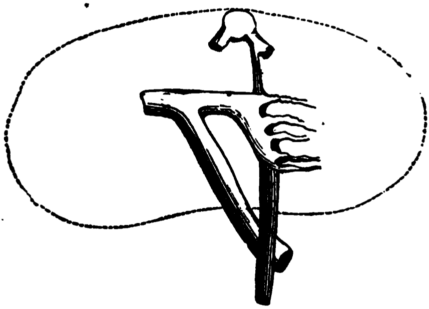


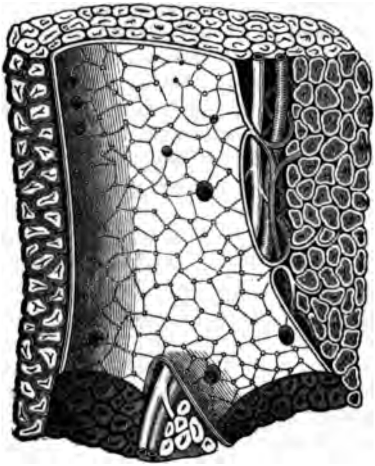
Diagram to represent the Circulation in Fœtal Liver.

conducted by the falciform ligament to the under surface of the liver, it sends off many branches to the left lobe, and none to the right, which is altogether supplied by the porta, the left branch of which joins the umbilical vein. The latter vessel then runs back to the cava under the name of ductus venosus, a tube which, like the umbilical trunk, closes after birth, whereas the left branches remain pervious, and carry the blood of the porta. The liver is very vascular, the blood for its nutrition being supplied by the hepatic artery. Around this vessel there entwine several branches from the solar plexus, and the right phrenic nerve also sends branches to the organ—

and the fact may account for the way in which the vicarious action of the liver and lung is stimulated.

Analyses of the gland tissue prove it to contain albumen, fat, and alkaline salts very freely, and about 68 per cent. of water. More recent analyses have shown that sugar is abundantly present. The coats of the liver are two, a serous and a fibrous, the capsule of *Glisson*, which its discoverer thought was muscular. *Kiernan*, whose famous investigations we have now to detail, regarded this capsule "to the liver what the pia-mater is to the brain;" and as it forms sheaths for the vessels, fills the spaces between the lobules, and forms part of the lobular tissue, he divided it into vaginal, interlobular, and lobular portions. The branches of the hepatic artery and porta, which enter the liver, and those of the duct, which leave it, can be similarly named. As to whether the capsule invests the lobules, all physiologists are not agreed, *Kiernan* and *Müller* contending that they are—a view very probably correct, as such a covering can be demonstrated in the pig and polar bear. *Bowman*, *Beale*, and others cannot find this capsule in man, so that the lobules are not distinctly isolated. As the larger branches of the porta run through the "portal canals," they are accompanied by branches of the artery, but $\frac{1}{5}$ their size, and of the duct, and are surrounded by loose areolar tissue, which allows them to collapse when cut across; not so the larger hepatic veins as they run towards the posterior thick edge of the gland, for no other vessels run with them, and if cut, they gape open, being fixed to the lobules around them. The hepatic veins may be said to begin by a vessel running through the centre of each lobule, "the intra-lobular." This ends in a vein along the base of each, "the sub-lobular," and these join the branches of the hepatic vein. The ultimate branches of the artery do not end in these hepatic veins, but in the lobular branches of the porta; and thus, besides supplying the nutrition of the gland, they yield bile after they have fulfilled their primary function. To the sides of the hepatic ducts are appended several small cœcal tubes, with very narrow openings into them. These are the vasa aberrantia, discovered by *Weber*, and they probably secrete mucus, or may act as "little gall-bladders."

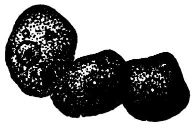
Before we leave the subject of the vascular supply, it may be mentioned that *Kiernan* has shown there is no separate red and yellow tissue as once supposed, but that such appearances are due to congestion of different vessels. Thus, when he tied the cava—or, if the return of blood through it was obstructed by cardiac or pulmonary disease, the intralobular vein filled with blood—and the surrounding tissue being more empty, gave the



Diagram, altered from Kiernan, *showing a Portal Canal containing a vaginal branch of the vena portæ, which gives off interlobular branches; also a branch of the duct and artery which lie to the right side. Just after the bifurcation of the vein, its branches are removed to show the canal which contains areolar tissue. Several lobules are seen—those above being normal, those to the right congested in their caval branches, and those to the left in the rare condition of portal congestion.*

appearance of a red centre on a yellow ground, whereas in portal congestion (a much rarer condition—only found in children), the centre was pale and the portal plexus engorged, presenting a yellow centre and red ground. The lobules (acini of *Malpighi*) are of a conical shape, with the base towards the surface of the liver or the portal and hepatic venous canals; the intralobular vein, running up like a midrib and branching laterally, gives them a foliate appearance. By transverse section they seem polyhedral, as if by mutual pressure.

Concerning the intimate structure of the lobules there is some obscurity, *Kiernan* stating them to consist of a capsule and plexuses of the vena portæ, artery, hepatic vein, and duct; and he appeals to the unravelled lobules in the left lateral ligament to support this view. There may also probably enter nerves and absorbents, which latter are remarkably abundant on the surface of the gland. Another disputed point is whether the secreting cells are placed among the capillaries, as believed by *Handfield Jones*, or are surrounded by a basement membrane continuous with the hepatic ducts, in the same way as all other glands—a view supported by *Beale* and most modern microscopists. The hepatic cells are of a somewhat rounded form, are well defined, and contain a nucleus and granules. They may be normally filled with bright, yellow pigment, or, in fatty liver, with numerous oil globules. Their diameter averages $\frac{1}{1500}$. These cells are the active agents in secreting bile, which they select from the lobular plexus of the vena portæ, in which have previously terminated the lobular branches of the artery after they have ministered to nutrition. That the porta affords the greater part of the bile, was shown by *Simon*, who tied it, and there was no bile secreted; whereas ligature of the artery produced no such effect—but it led to fatty degeneration of



The Hepatic Cells.

the whole organ in some recent experiments. The four cases recorded by *Lieutaud*, *Huber*, *Abernethy*, and *Lawrence*, where the vena portæ terminated in the cava, have been often urged as disproving that this vessel affords the bile; in *Abernethy's* case, however, the umbilical vein remained pervious, and branched out like the porta; and in the other instances there, very probably, was another vessel, more truly the porta, beginning in a *cul de sac*, and not receiving its ordinary tributaries. From this blood bile is separated, despite the fact that chemists cannot detect in it all its elements, as *Glisson* long ago expressed it, "peculiari colatorio."

The Bile is a most abundant secretion, about 54 ozs., including 2½ of solids, being daily poured out, according to *Bidder* and *Schmidt;* and *Dr. Budd* quotes cases where, by tapping distended gall-bladders, a quantity corresponding to over a pint daily was removed from the human subject. More is secreted on a flesh diet, and the greatest quantity about 15 hours after a meal. As obtained from the gall-bladder, where it may have undergone some changes, it has a specific gravity of about 1·028, and is alkaline, or according to *Boisson*, usually neutral. It is greenish yellow, to a depth differing much if spread out, or in large quantity, and has a bitter taste, followed by a sweetish after-taste. Its odour is faint, and somewhat like musk. It is viscid, froths if shaken, and feels like soap between the fingers. Scourers use it as a detergent. It tardily decomposes, especially if strained of mucus, and is supposed to have antiseptic power on the fæces, which are very fetid in jaundice, no bile acting on them. *Berzelius'* often-quoted analysis found ox-gall to contain—

Water	904·4
Bilin, fat, and pigment	80·0
Mucus	03·0
Salts (chloride of sodium, phosphates, &c.)	12·6
	1000·0

Free soda, the alkali present, and its salts are found in most animals, including fresh-water fishes; whereas, in those inhabiting sea-water, strange to say, the potash salts are substituted. The term "bilin" groups a number of substances of very different properties—for instance, the two peculiar acids which *Strecker* named cholic and choleic, corresponding respectively to the glycocholic and tauro-cholic acids of other chemists. The former contains nitrogen, but no sulphur; the latter contains both, and they are fatty acids united with soda sa a soap. As they cannot be found in the blood even after expiration of liver, they are supposed to be elaborated in the gland. The choleic or tauro-cholic acid, or its soda salt, hold the cholesterin dissolved. This fat has been described at page 44. Taurin, another body found in ox-gall, is a neutral crystalline substance, abounding in sulphur. Its formula is $C_4 H_7 N O_6 S_2$. *Strecker* has made it artificially from isethionate of ammonia. Biliphæin, or the pigment, is as yet imperfectly known. Its tints vary much, owing, perhaps, to the degree of oxidation. By the addition of an alkali, *Berzelius* obtained from it "biliverdin," a matter identical with chlorophyl, the colouring matter of leaves. I believe it is almost identical with the urine-pigment, and both are but altered conditions of the hæmatin. Effused blood, as in a bruise, shows every tint which either bile or urine possesses, and all three contain iron. The green stools and pale skin, which result from the action of mercury, are due to the blood-cells being destroyed in the over-stimulated liver; and I regard the suddenly fatal effect which *Moriarty* termed mercurial erethism, to be due to such a sudden impoverishment of the blood. Carbonate of soda has an effect contrary to that of mercury, for it checks the secretion, and was thus advised in cases of gallstones by *Prout*, who, however, erroneously supposed it saponified the cholesterin.

Bile may be recognised by the following tests, which are suitable when the physician searches for it in such fluids as urine, milk, sweat. *Simon's:* Add nitric acid to the fluid on a white plate or sheet of writing paper, and green, pink, and other tints play round wherever the acid falls. *Pettenkofer's:* To some of the fluid, in a tube, add ⅔ of sulphuric acid and a solution of sugar; a violet red colour appears if bile is present. As sugar and sulphuric acid produce a somewhat similar colour, especially if albumen or oil be present, the test is fallacious. It acts on the cholic acid and not on the pigment, as the same reaction occurs with decolorised bile.

The functions of the Liver are complex and not perfectly understood, but they appear to be—1. To rid the blood of hurtful matter, and—2. To elaborate matters of use in digestion and other nutritive acts. 1. That it is more excrementitious than digestive is suggested by its secretion being constant, like the urine—not occasional, like the gastric juice; it is separated from venous blood like urine—not from arterial, as most truly nutritive fluids are; and by the symptoms of poisoning which its sudden retention in the blood produces, being analogous to those which occur when the lungs or kidneys are interfered with (apnœa and uremia). However, in many instances the retained bile causes no injurious effects; and *Budd* accounts for those symptoms of poisoning it produces in others, by supposing that it becomes decomposed—just as urea must be changed before any signs of uremic poisoning occur.

Sulphur and colouring matters would seem to be the chief excreta, as all others are re-absorbed, only about 20 grs. daily appearing in fæces, though so great a quantity of bile is secreted. *Boerhaave*, 150 years ago, thus expressed this fact: "Almost the whole mass of the fluid secreted by the liver is again secerned or drunk up by the absorbing veins from the alimentary and fæcal contents before they arrive at the anus." 2. That it is not merely excrementitious is suggested by its duct always opening high in the alimentary canal, and was demonstrated by *Schwann's* experiment; he excluded the bile from the intestines by tying the duct, and then provided for its full excretion by discharging it externally through a fistulous opening. Of 18 dogs thus treated only 2 lived, and in them the duct had established another communication with the intestine. The others died in 2 or 3 weeks—emaciation, debility, unsteadiness of gait, and falling off of hairs having occurred, and gradually increased till death. It should not be concealed that similar experiments have obtained somewhat different results, and there are many cases where men have survived many months, though no bile passed through the digestive canals. We have no evidence that it acts chemically on the starch, fat, or nitrogenized portions of our food, save that it checks decomposition and evolution of gas, which occur so readily in jaundice. Out of the body it has been found to arrest alcoholic fermentation and putrefaction of flesh.

It is believed to be purgative by exciting the secretion of mucus, which will be found much more abundant wherever the bile has passed. Ox-gall has been given as a cathartic. Its use in promoting absorption of fat has been before alluded to. Its influences on the blood may be next mentioned, and they are so important as to earn for the gland the title of blood-refiner. *Weber*, by examining the rudiments of liver in the chick and in frogs, concluded that in it "a material is separated and accumulated from the blood, out of which the blood corpuscles are formed." The blood of the hepatic vein is said to be richer in white cells than that of porta, a fact advanced to support the theory just stated; but it is, on the contrary, a strong argument that the red-cells are disintegrated, and their hæmatin thrown off as bile-pigment, leaving the white cells proportionally more numerous. *Lehmann* believes the blood loses much fibrin by passing through the liver, being converted into glycin and taurin, and scarcely appearing in hepatic venous blood. This fact supports the view that fibrin is a compound beyond albumen in the downward course (see p. 115). The chemical changes which occur in the liver are sources of animal heat, and *Bernard* found the temperature of that in hepatic vein higher than that of porta or aorta. The liver and lungs have been regarded as vicarious in performing the great acts of respiration and calorifaction; and the great size of the former in fœtal life and herbivora, where the action of the lungs is either not developed or exerted in a degree far below that of carnivora, supports the doctrine, which, however, the great size of the gland in the boa and other cold-blooded animals throws doubt on. Two heat-giving materials are generated in the liver—namely, fat, which is found abundantly in the hepatic cells, and sugar.

The Glycogenic Function of the liver was discovered and profoundly investigated in 1848 by *Claude Bernard.* He found sugar in the liver of carnivora, and still more in herbivora, from the starchy and saccharine nature of their food; but it was present in dogs after they had been fed for eight months on calves' heads and tripe, all vegetable food being excluded. That it is not due to digestive action, but to a power inherent in the liver, is shown by its occurring in animals kept long fasting, and when no trace can be found in the blood of porta or hepatic artery. The fresh liver of the horse contains about 4, man 2, and reptiles about 1 per cent. The hepatose, or liver sugar, obeys every test which produces re-actions with grape sugar, and will yield alcohol by fermentation, when injected into the veins. It differs, by so readily undergoing decomposition and never escaping with the urine. The capillaries—or, according to *Handfield Jones,* the hepatic cells—are the organs which elaborate it; and he regards these cells as not within the ducts, and thus unconnected with the secretion of bile.

Dr. Pavy regards the formation of sugar as an occurrence after the death of the animal, and has performed many experiments to support this view. The matter which is convertible into sugar he calls "the amyloid substance," and assigns it the formula $C_{12}\ H_{12}\ O_{12}$. In two instances—the liver of a cod and of a rabbit—he found this matter not changed into sugar even many hours after death; but the change usually occurs most rapidly. *Brücke*, and some English analysts, have demonstrated that urine normally contains sugar; and if so much sugar were formed in the liver as *Bernard* avers, it would be excreted, and we would be all suffering from diabetes mellitus.

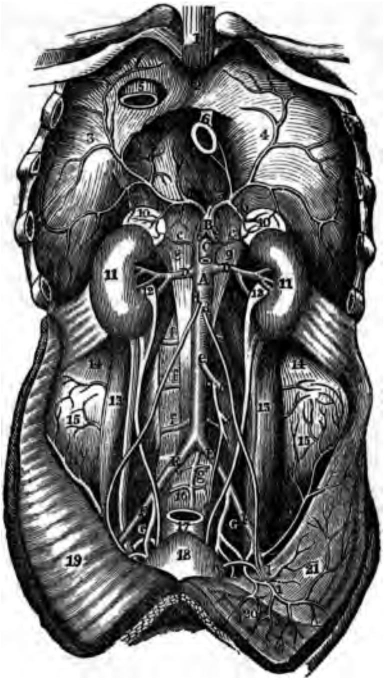
Even after the tissue has been washed, and all sugar dissolved out by injecting water, still it will generate sugar if left aside for 24 hours. A maximum amount of sugar is formed about 4 or 5 hours after a meal. If starch or other kinds of sugar are taken, they are absorbed by the vena portæ, and changed in the liver into hepatose. From the liver the hepatose is carried to the lungs through the right side of heart, where it can be obtained plentifully; it disappears almost completely in the lungs, for the blood at the left side of the heart scarcely contains a trace. The only vessels from which it is completely absent are those of the chylopoietic viscera, when none had been recently taken with food. *Harley* has determined the important fact, that alcohol and other stimulants injected into the vena portæ, will excite the liver to so great an increase of its glycogenic function, that sugar will be excreted by the kidneys. Diabetes has been often due to the habitual use of intoxicating liquids. *Bernard* states that the changes of the sugar in the lung are not simple oxidation and the production of carbonic acid; and *Lehmann* suggests that it ferments, becomes lactic acid, which, acting on the carbonate of soda in the blood, sets free carbonic acid, and forms lactate of soda. The ferment which is necessary to produce these changes is fibrin, and it has been found that defibrinated blood if charged with sugar, may pass through the pulmonary circulation without any loss of sugar. Another necessary condition of the blood is its alkalinity. Besides such offices in connexion with aeration of the blood, *Bernard* regards sugar as required for the development of the blood-cells.

Another remarkable discovery of *Bernard's* was the influence of the nervous system on the glycogenic function. If the pneumogastrics be divided, no sugar whatever is formed in the liver. The contrary occurs, and sugar is formed so abundantly, that it passes off by the urine, constituting "an artificial diabetes," when the floor of the 4th ventricle is irritated or injured. *Bernard* justly supposes that it is secreted by a reflex influence, transmitted from the lungs to the medulla, and thence sent down the spinal cord, section of which checks its formation; whereas the pneumogastrics may be divided below the lungs without any interference, and if they are divided in the neck, galvanizing the upper end will excite the formation of sugar. The effect of the want of due aeration, as in fœtal and very advanced life, during the administration of chloroform, and in all diseases affecting the respiratory organs, will be again referred to, as the latter circumstances are powerful causes of diabetes. During fœtal life the placenta performs a glycogenic function. *Dr. R. M'Donnell* has communicated to the Royal Irish Academy some most important observations, which go to prove that the amyloid substance is but a stage between the ternary and quaternary compounds, and is in progress of assimilation. He has found it in the following situations besides the liver—the placenta, many parts of fœtus, muscles and lungs of hybernating animals, and in paralysed muscles. I have much pleasure in referring to his valuable memoirs in the *Natural History Review* for July, 1860, and that in the *Dublin Journal*, August, 1859, for an admirable account of the subject.

A few words as to the means we possess of controlling the action of the liver may be appropriate, and firstly as regards diet. Rich meats require much bile for their assimilation, and become, especially in warm weather or climate, a frequent cause of bilious vomiting and diarrhœa, while stomachic digestion is arrested by the presence of bile. Exercise promotes respiration, increases the evolution of carbonic acid, and rids the blood of the hydro-carbonaceous matters the liver generates; the want of it, therefore, must act most seriously on hepatic function—sallow skin, sluggish liver, dulled brain, and torpid bowels being some of the results. Some persons seem born with livers in which the secreting elements are deficient, and thus possess an innate proclivity to hepatic disease. In the words of *Budd*, "The chief conditions to diminish the quantity of matter which the liver is called on to excrete, are—a light diet, with water for drink, active exercise, early rising, and a cool or temperate climate." Cholagogues, or medicines which excite the flow of bile, do so probably by passing through the gland; and among them mercury and iodide of potassium have been discovered in the bile after they were introduced into the circulation. The same is also, perhaps, the case with taraxacum, podophyllin, and sal-ammoniac, which stimulate the liver powerfully. Spices and some purgatives excite the flow of bile by irritating the neighbouring mucous surface of stomach and duodenum.

THE KIDNEY.

The most complete example of an excretion is the urine, as it is cast off without fulfilling any useful purpose. The kidneys separate this fluid from the blood, which contains most of its constituents preformed. These glands are about 4oz. each in weight, and receive the renal artery from aorta, and send the emulgent vein to the cava, these vessels being quite out of proportion, to the nutritive requirements of the organs. The nerves are abundant, being derived from the lesser splanchnic of sympathetic, and their twigs can be traced as far as the inferent vessels. The ureter or duct



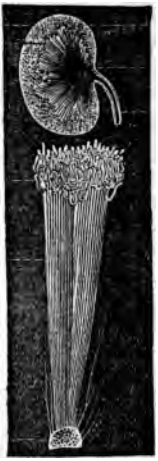
The Kidneys and their vascular relations.

A. Abdominal Aorta between the Pillars of the Diaphragm. B. Cœliac Axis, dividing into the Gastric, Hepatic, and Splenic Arteries. C. Superior Mesenteric Artery, cut. D, D. Renal Arteries. d, d. Spermatic Arteries. 1. *Xiphoid Cartilage or Appendix.* 2, 3, 4. *Diaphragm.* 5. *Opening for Inferior Cava.* 6. *Œsophageal Opening.* 7. *Union of the Pillars.* 8, 9. *Pillars of the Diaphragm.* 10, 10. *Supra-Renal Capsules.* 11, 11. *The Kidneys.* 12, 12. *Pelvis of the Kidney.* 17. *Rectum.* 18. *Urinary Bladder.*

emerges from the hilus, where it is dilated into a pelvis. Kidney tissue has a specific gravity of about 1·050, and consists per cent., according to *Beale's* analysis, of 76 of water, 15 of albumen, and other nitrogenized matter, and 1 of fat, chiefly cholesterin. There has been found also inosite, cystin, taurin, and xanthin.

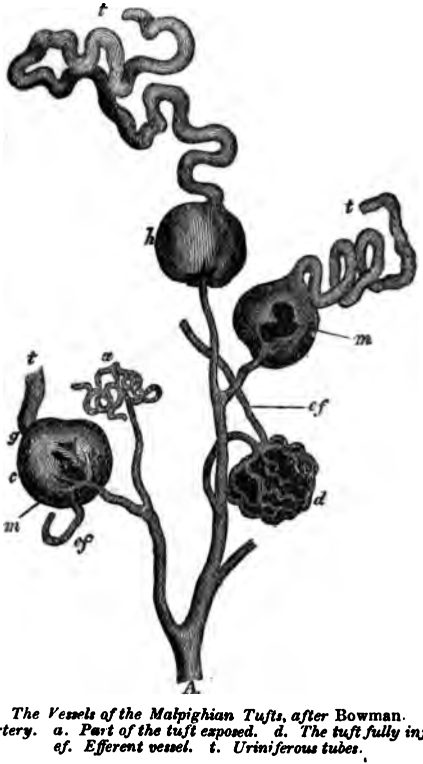
The Coats of the kidney are—1. A very scanty serous covering in front. 2. A fatty envelope, more abundant behind, and which *Cruveilhier* thinks keeps up the temperature of the gland, fat being so bad a conductor of heat. 3. A strong fibrous capsule, which is easily peeled off, yet is continuous with the areolar parenchyma of the organ, which *Goodsir* terms the matrix. *Beale* denies any such matrix; and *Mr. Richardson* thinks the fibrous appearance due to the crumpled and collapsed state of the membranous walls of the tubes and capillaries. A small quantity of transparent, faintly granular, nucleated material is found between the tubes and capillaries. The adult kidney sometimes shows division into lobules, or renculi on the surface, an arrangement which is very apparent in the fœtus, and in the whale, bear, ox, and other mammals. When the organ is divided longitudinally, the naked eye perceives two distinct structures—1. The cortical portion, rough, granular, and vascular; having here and there small red dots (Malpighian tufts), and 2. Medullary, which consist of about 15 pyramids, composed of straight tubes opening on the papillæ or conical points formed by 1, 2, or 3 pyramids. Each papilla is surrounded by a mucous cap or calyx, opening into the cavity of the kidney, which is shaped into 3 infundibula, and continuous, by the pelvis, with the ureter. The cortical matter dips between the pyramids, forming what are called the columns of *Bertin*.

Such are the appearances visible to the naked eye, which are roughly figured on the following page; but the microscope shows the gland to be made up of very minute ducts, "the tubuli uriniferi." These are straight and more easily seen in the pyramids, and are here termed the tubes of *Bellini*. The part towards the cortex is convoluted, as noticed by *Ferrein*, and they end in a flask-like, dilated extremity. This extremity sends a capsule, according to *Müller*, doubly folded, like the peritoneum, round each Malpighian tuft; others believe that the capillaries are here naked. The epithelium is only continued for $\frac{1}{3}$ up the capsule in man, but all through it in the proteus. The cells are not ciliated in mammals, but are so in reptiles, as readily seen in the newt and in the fowl. The convoluted tube is about $\frac{1}{480}$ as it leaves the flask-like dilatation, but diminishes to one-half before it joins the straight tube; these latter, by joining others, become less numerous, but larger, so as to measure $\frac{1}{200}$ when they open on the papillæ.



Section of Kidney and enlarged view of the Uriniferous Tubes.

The Branches of the Renal Artery first send off ordinary nutrient branches, then run between the pyramids till they arrive at the cortical substance, when they give a twig to each capsule. This vessel is named the "vas inferens," and entering the capsule it breaks up into numerous capillaries rolled into a circular form, constituting the "Malpighian tuft." The disposition of the vessels and tubes is shown in the figures after *Bowman* on the two following pages. A vein, or "vas efferens," emerges near the point where the artery or vas inferens entered, and, passing between the tubes, forms an intricate plexus. This vein, then, as it begins and ends in capillaries, and, as we shall see presently, secretes the essential part of the urine, closely resembles the porta in the liver, and for these reasons was appropriately termed "the portal system" by *Bowman*, who says, "Each one of these efferent vessels is truly a portal vein in miniature." The analogy is still stronger in



The Vessels of the Malpighian Tufts, after Bowman.
A. Artery. a. Part of the tuft exposed. d. The tuft fully injected.
ef. Efferent vessel. t. Uriniferous tubes.

the boa, some other reptiles, and a few birds, as the vessel which supplies the kidney is a branch of the porta.

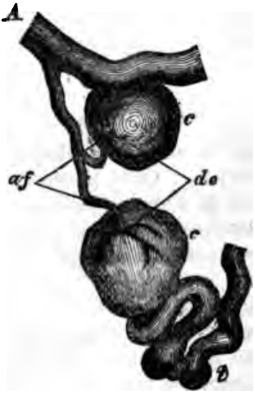
Mr. Richardson, Examiner in anatomy and physiology in the Royal College of Surgeons in Ireland, has succeeded in making some most admirable injections, and has very kindly drawn the following figures with the aid of the neutral tint-glass reflector. He uses the following injecting fluid:

Purified sulphate of iron.........	10 grains.
Ferridcyanide of potassium......	82 ,,
Wood naphtha.........	1½ drachms.
Glycerin (*Price's*)................	1 ounce.
Spirits of wine.....................	1 ,,
Water................................	4 ,,

The precipitate obtained by mixing the solutions of the two salts should be well washed before adding the other fluid ingredients. Sections of the tissue injected with this fluid should then be placed in a vessel of cold water, which is to be changed until it ceases to be milky. They are then to be placed for some days, or until they become transparent, in the following preserving fluid:

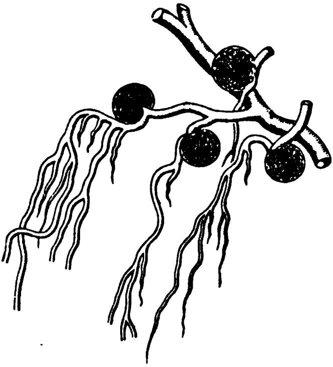
Saturated solution of tartaric acid	1 drachm.
Glycerin	1 ounce.

The preparations may then be mounted in cells, and they are truly remarkable for clearness of outline and brilliancy of colour. The first figure on the following page, which is from one of *Mr. Richardson's* preparations, shows some vasa recta formed by the efferent vessels. One of them is seen to cross the artery, and, as he remarks, might be readily supposed to arise from it. *Virchow* believes that all the vasa recta are derived from the artery

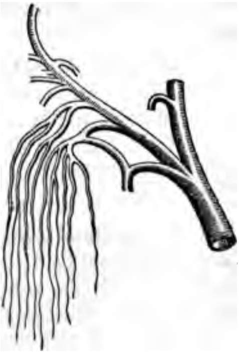


Two Malpighian Tufts injected. af. Afferent vessels. cc. Glomeruli. t. Uriniferous tube.

directly, as represented in the second figure (copied from that in *Virchow's* "Archiv für Pathologische Anatomie und Physiologie und für Klinische Medecin"), and that their purpose is to obviate venous congestion, for if the Malpighian circulation be obstructed blood can escape through these vessels. This object might be partly accomplished by the blood escaping into the nutrient arteries on the surface of the organ, and congestion is much more frequent in the portal system when, from obstruction of the tubes, the blood cannot rid itself of the elements of the urine, and this condition might be readily relieved through those of the efferent veins, which become vasa recta. The peculiar straight course of these vessels is destined to accommodate them to the arrangement of the tubes in the pyramids. The accompanying plan of the renal circulation on the following page, will render my description more intelligible. In so far as that a single section will rarely show all the appearances depicted, it is diagrammatic; but each portion of it is faithfully delineated from *Mr. Richardson's* admirable preparations. The artery is observed first to

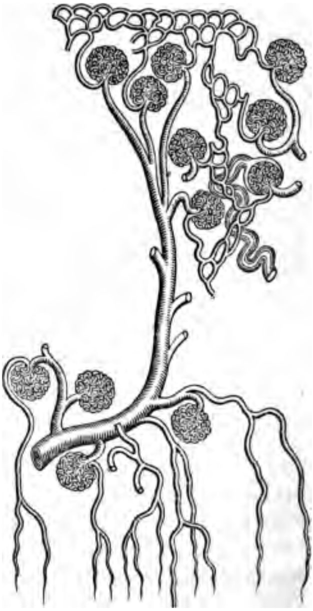


Venous Vasa Recta.



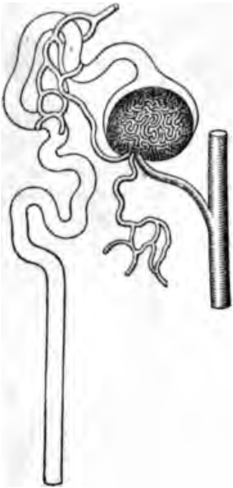
Arterial Vasa Recta.

take a horizontal direction along the line of junction of the cortical and medullary structures, giving off inferent vessels, a vas rectum, and, just as it bends upwards, a branch which bifurcates into an inferent vessel and a vas rectum. The efferent vessels are represented, becoming straight (venous vasa recta) in this portion of the kidney, and one is divided in the section, just as it crosses the arterial trunk; and the fallacy of supposing it to spring from it might occur to any but an experienced observer. The artery then runs up towards the cortex, giving off an inferent vessel to each tuft, from which emerge the efferent veins, which then form the "portal system." Some of them form a plexus, coating the surface of the kidney, while others break into an intricate plexus round a uriniferous tube, which is seen to the right of the figure. *Mr. Richardson* demonstrated before the Surgical Society the occasional duality of the efferent vessels.



The Renal Circulation.

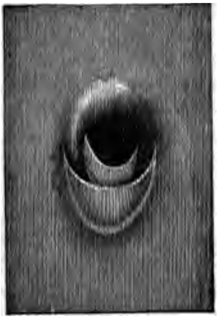
Bernard assigned a peculiarity to the renal circulation, asserting that the blood in the porta, after ingestion of food, flowed partly into the cava—hence, was pumped into the renal veins, and was purified in the kidney before mixing in the general circulation. The urine which is then secreted is that termed urina cibi. This



Tuft with Two Efferent Veins.

hepatico-renal circulation has been disproved by many ingenious experiments of *Dr. R. M'Donnell* of the Carmichael school, who has found a special valve at the mouth of the renal vein, where it joins the cava for the purpose apparently of preventing renal congestion.

The Malpighian Tufts are about a $\frac{1}{100}$ in diameter, and being sometimes very red, can be seen by the naked eye in the cortex. When a number of them are seen attached to their inferent vessels, they resemble a bunch of currants. So extensive is the secreting surface of the kidneys, that it is said to be six times greater than the whole skin. The water of the urine is separated from the blood of the Malpighian tuft by simple oozing through the membrane which divides it from the cavity of the tube. No epithelium is necessary in this place, save in reptiles, where the urine is solid, and is separated all through the tube by gland cells. The nuclei in the capillaries of the Malpighian tufts have been mistaken by some observers for epithelium within the tubes. *Mr. Bowman* (from whose masterly account nearly all our knowledge of the subject is derived) remarks that no other arrangement for the separation of water could be so effective, for the blood flowing from several capilla-



Vena Cava laid open to show the Valve at Renal Vein.

ries into a vein of far less calibre than theirs united, must have its velocity much decreased, a circumstance most favourable to the exudation of water. The water has then but to pass through the walls of the capillaries and the end of the tube, and rushing down, must serve to force before it the solid matters secreted further on. Unlike abnormal exudations from the blood, there is no albumen passed through, save in *Bright's* disease, and some other affections hereafter alluded to. The urea, salts, &c., are secreted from the blood of the portal plexus surrounding the tube by the glandular epithelium within it. These gland-cells are supposed to be permanent, not bursting like others when filled with the secreted product. They have been found filled with crystals of uric acid, &c., in urine. The epithelium in the lowest part of the tube is pale and tesselated, and towards the ureter, becomes columnar, which variety retains till the bladder, where the mucous coat is covered with very large nucleated cells.

The Ureters are very dilatable tubes, having an outer longitudinal and an inner circular unstriped muscular coat, in which vermicular contractions occur. Their openings into the bladder are so oblique, so narrow and valve-like, that there can be no need of such muscles as *Sir C. Bell* described to hinder the reflux of urine; and *Mr. Ledwich* describes the tissue of these bands and the trigone as elastic. In cases of ectopia vesicæ, the ureters have been observed to pour out urine alternately.

The Bladder has coats which in position and number are identical with those of stomach, viz., serous, areolar, longitudinal, circular, and reticulated muscular, fibrous, and, lastly, mucous. The circular muscular fibres form round the neck a "sphincter vesicæ." That the neck of the bladder is muscular, was the opinion of *Bell* and *Meckel*, and seems proved by the occurrence of spasm (dysuria or strangury) from many morbid irritations. *Bichat*, *Magendie*, and others regarded it as elastic, on account of the urine being retained after injury to the spinal cord. *Prof. Harrison* demonstrated elastic tissue below in the situation of the uvula and muscular fibres in other directions. The internal muscular coat is reticulated, and when hypertrophied, comes to resemble closely the columnar surface of the heart, especially the apicial bands, according to *Mr. Ledwich.* The mucous membrane of the bladder is pale, loose, and rugous, save at the "trigone," where it is smooth, fixed, and vascular.

The Male Urethra has walls undoubtedly muscular, *Hancock* having traced that tissue from the longitudinal fibres of the bladder. They may give rise to spasmodic stricture, especially in the membranous portion, where two layers lie close to the mucous coat. Here, too, can be demonstrated striped fibres, constituting "*Wilson's* muscle," which *Mr. Ledwich* has always succeeded in finding, and "*Guthrie's* muscle," which is not so constant. The lodgment of the last few drops of water is prevented by the action of the accelerator urinæ.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Define secretion, and say what chemical substances are removed by the process.
2. Describe the structure of the mammary gland, and compare it with the testis.
3. Sketch the circulation of the fœtal liver.
4. What are the contents of a "portal canal?"
5. Give the chemical composition and uses of the bile.
6. Describe that part of the renal vessels where it is supposed the water of the urine escapes.

SENIOR.

1. What are the respective influences of cerebro-spinal and sympathetic nerves on secretion?
2. Give the composition of milk, noting the differences presented at various periods, and by that of the cow.
3. Describe the minute anatomy of the liver, mentioning the opinions held as to the position of the hepatic cells.
4. Sketch the functions of the liver, including that discovered by *Bernard.*

5. Describe *Mr. Richardson's* method of preparing injections of the renal vessels.

6. What are the supposed sources and uses of the straight vessels of the kidney?

THE URINE

Is a clear, pale yellow liquid, with a saline taste and a peculiar aromatic odour when first passed, or in a much stronger degree when a drop of it is heated on platina foil. Its reaction is slightly acid, which, as well as colour and smell, is due to the urophæin, according to *Heller*. The more concentrated the urine the greater the acidity, colour, and smell. Others assign the acid reaction to lactic acid, and *Liebig* to acid phosphate, which view is supported by its being much less acid, or even alkaline during digestion, especially of animal food, that salt being the solvent of gastric juice, according to *Blondlot*. The urine of carnivora is acid, that of herbivora alkaline, save during fasting, when they may be regarded as feeding on their own tissues. The amount of acidity of the urine of 24 hours equals about that of 30 grs. of oxalic acid. The specific gravity is on average 1·020, but ranging much above and below this even in health, mainly according to ingestion of food; thus, that passed shortly after a meal (urina cibi) has a high density; that passed in the morning (urina sanguinis) a medium, and is most suitable for examination; and that passed after drinking (urina potus) is most watery.

The average quantity *Dr. Prout* stated to be 30 to 40 ozs. daily, the former being the average of summer when the skin discharges so much water, and the latter the quantity passed in winter and moist weather. *Dr. Thudichum's* average, viz., 65 ozs., is much too high. There is eliminated about 650 grs. of solid matter in this quantity of urine; and this can be always roughly estimated by taking the specific gravity, and multiplying its excess above 1000 by 2·33, according to *Dr. Christison's* formula. If the specific gravity be then 1·020, the number of grains of solid matter in 1000 grs. of urine will be 46·60, half this if the specific gravity be 1·010, and double it if 1·040. Another simple rule is, that the two last figures of the specific gravity, if under 10·30, give the number of grains of solids in an ounce. Man loses daily by the kidneys about 1/40 of his weight, and a child nearly twice that amount. Urine forms 46½ per cent. of the entire egesta, pulmonary exhalation 32, cutaneous excretion 17, and fæces 4½. Urine deposits a cloud of mucus in about 2 hours, or more rapidly if cooled, in which the microscope shows epithelial scales. After some time longer it becomes more highly acid from the formation of lactic acid, which, uniting with the bases of the urates, throws down uric acid. In some instances oxalic acid or oxalate of lime is precipitated. At a still later period it undergoes alkaline fermentation, the urea being changed into carbonate of ammonia, the phosphates deposited, and ammonia, with its characteristic smell, being evolved. This change occurs more rapidly in the bladder, owing to the higher temperature.

The Composition of Healthy Urine, specific gravity 1·020, is exhibited in *Prof. Miller's* analysis:

Water			956·80
Solids 43·2	Organic matter 29·79.	Urea	14·23
		Uric acid	0·37
		Alcoholic extract	12·53
		Watery extract	2·50
		Vesical mucus	0·16
	Fixed Salts 13·35.	Chloride of sodium	7·22
		Phosphoric acid	2·12
		Sulphuric acid	1·70
		Lime	0·21
		Magnesia	0·12
		Potash	1·93
		Soda	0·05

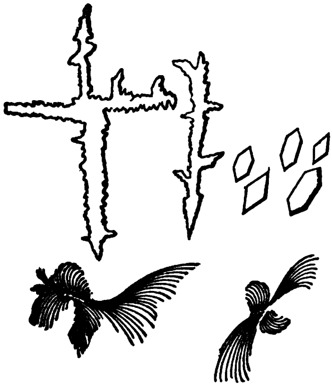
Prof. Day gives the following table of the daily average quantities of the constituents of urine; specific gravity 1·020—52 ounces containing 935 grains of solids:

	Grains.
Urea	520
Uric acid	8
Hippuric acid	traces.
Xanthin	,,
Hypoxanthin	,,
Creatinin	7·0
Creatin	4·5
Extractive	variable.
Chloride of sodium	266
Sulphuric acid	32
Phosphoric acid	54
Earthy phosphates	15
Ammonia (?)	11
Iron	traces.
Silica	,,
Fluorine	,,
Gases	undetermined.

Urine contains, per volume, 45 parts of carbonic acid if fasting, 100 parts if digesting, 8 of nitrogen, and 0·6 of oxygen in the 1000.

We shall now examine in detail the most important substances contained in urine during health, and the variations under disease, and firstly the nitrogenized bodies.

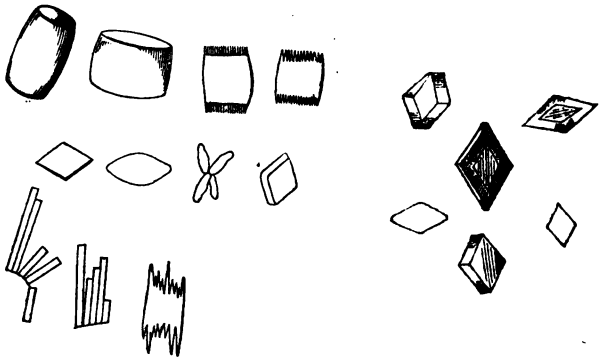
Urea, which was discovered by *Cruikshank*, is a weak base uniting with acids, but not showing the other tests of alkaline reaction. It is inodorous, has a cooling, saline taste, and is soluble in its own weight of water. Its composition is shown by the formula $C_2 H_4 N_2 O_2$, and it is metameric with cyanate of ammonia, as discovered by *Wohler* ($H_4 N O, C_2 N O = C_2 H_4 N_2 O_2$). It can be prepared artificially. Urine, if evaporated in a watch-glass to $\frac{1}{8}$, yields crystals of nitrate of urea on adding nitric acid, which can be then removed by carbonate of baryta, leaving the urea pure. It fuses at 248°, at a higher heat gives off carbonate of ammonia, and leaves cyanic acid. The crystals of the nitrate are of the forms seen in the annexed figure.—The diurnal quantity is stated most variously by several chemists; thus, *Becquerel* 295 grains, *Parkes* 346, *Lecanu* 433, *Lehmann* 500, and the *Rev. Professor Haughton* obtained 576 grains from "well-fed, flesh-eating, wine-drinking men," and but 394 "from well-fed, water-drinking vegetarians." The last accurate observer gives the following bed-side rule for ascertaining its amount: "Half the excess of specific gravity of urine (not containing either sugar or albumen) above 1000, is the number of grains of urea per fluid ounce." *Professor Davy* of the Royal Dublin Society has discovered the following beautiful method of quantitative analysis:—Place a measured quantity of the fluid containing urea in a glass tube partly filled with mercury, add an excess of solution of hypochlorite of soda, and then invert the tube. The urea is decomposed into water, carbonic acid (which the fluid absorbs), and nitrogen, whose amount in the top of the tube indicates the quantity of urea.


Nitrate of Urea.

The source of urea is either the waste of the nitrogenized tissues, especially muscular, or by the direct destruction of nitrogenized food. *Liebig* and *Bischoff* maintain the first view, as it is still excreted after 3 weeks' fasting, and is much increased by exercise. *Lehmann* and *Frerichs*, on the other hand, believe that the nature and quality of food influence the amount of urea. It is increased after meals; and *Bechamp*, by digesting albuminoids with permanganate of potash, has converted them into urea. His results have been questioned by *Staedeler*. Gelatin appears to form urea directly, not being appropriated by any tissue. Again, *Draper* found that the amount varied but slightly in a person kept at perfect rest while being treated for a fractured leg, and in another man who walked 13 miles daily at the rate of 4½ miles per hour.

Much less is secreted during sleep, which is due either to diminished mental or muscular activity. *Professor Haughton* thinks mental exertion greatly increases the amount of urea. He thus assigns 533 grains as the daily average for the student, 400 for the physical labourer. Urea is not formed in the kidney, but is merely separated from the blood—so rapidly, however, that without taking great quantities of that fluid no trace can be obtained. As discovered by *Prevost* and *Dumas*, if the kidney be extirpated its amount increases to 1·4 per 1,000 of blood; while some of it, by the addition of water, is converted into carbonàte of ammonia, and thus evolved from the mucous surfaces. In man disorganization of the kidneys is often so complete as to render impossible any separation of urea, which, being retained in the blood, often inflames the serous membranes, or if the retention be sudden, produces symptoms of narcotic poisoning, usually called "renal coma." *Frerichs* thinks such effects due to the conversion of the urea into carbonate of ammonia, which cannot, however, be usually detected in the breath. Urea is not a poison when taken into the digestive canal, for *Segalas* administered it as a diuretic in dropsy. *Prof. Parkes* states that liquor potassæ increases the amount of urea, as also does common salt. Alcohol, tea, &c., according to *Böcker*, check its excretion. Disease sometimes increases the quantity excreted—a morbid condition, termed by *Prout* diabetes ureosus, or azoturia. *Warncke* (whose essay has been translated by that elegant scholar, *Dr. W. D. Moore*) found it increased during the first week of typhoid fever, after which it gradually decreased. This circumstance is diagnostic from gastric fever, in which it is at first decreased, and gradually rises in amount. 1,250 grains were daily excreted in pyemia, and 1,100 in fevers. Its amount is much decreased in cancerous cachexy, and lowered to ¼ its normal standard in *Bright's* disease, and *Thudichum* relates a case of ovarian tumour where but 75 grains passed daily. It occurred in the muscular substance of a cholera patient, in which tissue it cannot be found in health. The fluids of the eye and the liquor amnii normally contain urea.

Uric Acid ($C_{10}H_4N_4O_6$) constitutes about $\frac{1}{1000}$ of human urine, being combined with soda and ammonia, and, as some state, with lime. It is very insoluble. The almost solid urine of serpents and birds (guano) contains even 90 per cent. of urates. Carnivora excrete more of it than man, and the urine of herbivora contains none. It is a very weak acid, not reddening litmus, and displacing only a part of the carbonic acid combined with the base, thus converting a carbonate into a bicarbonate. Uric acid can be obtained by adding hydrochloric acid to urine, when in a few hours it subsides in beautiful crystalline grains, stained red by the colouring matter. Some of its crystalline forms are figured in the following page, that in the centre of the second figure having been observed by *Mr. Richardson*. Its presence is easily detected by forming murexid, or purpurate of ammonia of *Prout* (its discoverer), a splendid purple substance. To produce this reaction a little of the urine is heated on a slip of glass with a drop of nitric acid; ammonia is next added to the dried residue, when a crimson colour appears, changing to purple if liquor potassæ be poured on it. The colour disappears on heating. Thein gives a similar reaction.



Uric Acid.

Uric acid appears to be a result of the oxidation of of nitrogenous tissues and food, further oxidation, according to *Liebig*, producing urea; so that *Haughton* regards the presence of uric acid as abnormal.

Diminished perspiration, respiration, or exercise, and increased animal food, augment the quantity excreted.

Acute inflammatory diseases, gout and rheumatism, increase the quantity of uric acid generated in the system; but more of it will be passed with the urine when they are subsiding. *Parkes* procured 17·28 grains daily from a fever patient. *Dr. Garrod* has detected urate of soda in the blood of gouty patients, from whose urine it disappears before an attack of gout, which is then due to its accumulation in the blood. The readiest way to obtain uric acid from the blood of a gouty patient, is to apply a blister and add acetic acid to the blister-serum, through which a fine thread is passed; it soon crystallizes upon the thread. Tophi or chalk stones are composed of urate of soda; hence physicians prefer potash or lithia as remedy for gout, the salts they form being soluble. These deposits are formed about the smaller joints, and, as *Dr. Benson* has observed, under the skin of the ear. I had lately the advantage of observing the action of lithia employed by *Dr. Garrod* in the University College Hospital. In many debilitating diseases, chlorosis, hysteria, ramollissement, spermatorrhœa, &c., the amount of uric acid may be decreased one-half. *Liebig's* theory that excess of uric acid occurs in diseases where the oxygenation of the blood is prevented, is not supported by clinical observation. The dependence of lithuria on obstructed action of the skin, and the eliminative and curative power of that surface are well established; and uric acid calculi rarely occur in warm climates, where cutaneous excretion is abundant. *Bird* found crystals of urate of soda in eczematous discharges from gouty patients. Among remedial agents whose actions the physiological source and chemical properties of uric acid explain, may be mentioned exercise, diminished animal food, diaphoretics, and such solvents as potash, and its salts with organic acids, lithia used by *Garrod*, phosphate of soda suggested by *Liebig*, and benzoic acid recommended by *Ure*.

Hippuric Acid (C_{18} H_8 NO_5 HO), discovered by *Liebig*, is found in the urine of horses—hence its name—of cows, which contain 1·3 per cent., and some other vegetable feeders. Uric acid replaces it in the urine of all animals while suckling. A minute trace can be discovered in human urine, and a large quantity was daily excreted by a patient of *Mr. Tuffnell*, in the Military Prison. Hydrochloric acid throws it down, as it does uric acid, than which it is much more soluble, and distinctly acid, reddening litmus at once. *Ure* found that benzoic acid, cinnamic acid, or oil of bitter almonds, if taken, were converted into hippuric acid, and so carried off in urine. A converse change is said to occur if cow's urine be allowed to become stale, hippuric changing into benzoic acid, an occurrence which also takes place in horses if overworked. After bile and purpurine, hippuric acid contains more carbon than any other substance obtainable from the human body. With regard to its physiological and pathological relations we know little, save that it has been found in the blood of oxen, that it appears analogous to bile-pigment, and is absent from the urine in jaundice.

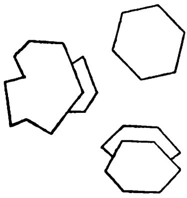
Creatin and Creatinin are two other nitrogenized products discovered in the urine by *Pettenkofer*, and proved to exist in muscle-juice by *Liebig*, a pound of flesh giving about 5 grains of the former. Their chemical composition only differs in creatin containing two more equivalents of water. Creatin has been discovered in the blood. Four grains of creatin and 7 of creatinin are daily excreted, the amount being proportional to muscular waste. The heart yields most creatin.

Kiestin is a term applied to a substance which rises, as a cotton-like cloud, to the surface of the urine of pregnant women. It is said by some to be merely a mixture of ammoniaco-magnesian phosphate and fungoid growths developed by putrescence, and by others to be composed of a fatty and a casein-like substance, thus excreted while the blood contains casein and no milk is produced. Its peculiar appearance, and cheese-like odour when putrifying, afford reliable signs of pregnancy or mole-pregnancy.

We shall here describe two nitrogenized bodies which can be hardly assigned as normal constituents, though there is some reason to suppose they exist in, or are formed from the extractives.

Xanthin, or uric oxide, is a very rare constituent of calculi discovered by *Dr. Marcet*, and never has occurred except in children. Its chemical characters are very similar to those of guanin and hypo-xanthin, which may be found abundantly in the spleen and cirrhosed liver. *Bence Jones* is the only chemist who has found it crystalline. It forms the greater part of the urine of the arachnids. Nothing physiological or pathological is known about this substance.

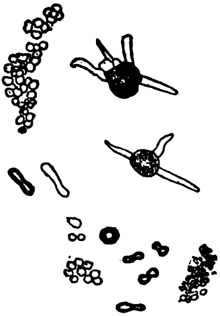
Cystin, discovered by *Dr. Wollaston*, is remarkable for the great amount of sulphur (26 per cent.) it contains, and is thus recognized by its smell when burned on platina foil. When in sediments it is always crystalline, and forms six-sided scales, as here represented. It has chiefly occurred in chlorotic and strumous persons, with sometimes an hereditary tendency. As it indicates an insufficient supply of oxygen, *Dr. Prout* advised the exhibition of nitro-muriatic acid. *Prof. Ronalds*, late of Queen's College, Galway, found 3 to 5 grains of sulphur, probably from the albuminoids and taurin, daily excreted in the extractive.



Cystin.

Urophœin, or the urine-pigment, is another nitrogenized body about which much obscurity still prevails. *Heller* states that the acid reaction and smell of urine, as well as the colour, are due to it. It is very similar to blood-pigment, and may be a product of the destruction of blood-cells. By it large quantities of carbon are got rid of, especially if the liver or lungs are diseased, so that the kidneys seem compensatory to these organs.

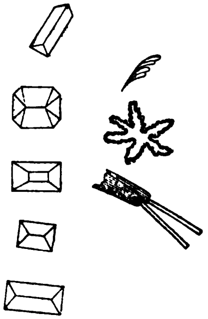
Various other colouring matters have been described in the urine. They all contain nitrogen, and usually a trace of iron, and are probably but altered conditions of the blood pigment. Urophœin is that which is best known, and its quantity and the depth of colour are proportional, save in diabetic urine, to the specific gravity. Indican, a blue pigment almost identical with indigo, exists in nearly every specimen of urine, and was discovered by *Carter* in the blood. Ammonia probably does not exist in fresh, healthy urine, but is often evolved as the nitrogenized matters decompose. In combination with uric acid, urate of ammonia, it occurs in solution or in many febrile states as a plentiful brick-dust or lateritious amorphous sediment, or in crystals, such as here represented, the projections from the spheres, however, being urate of soda. This ammoniacal salt is recognized by its being dissolved by heat and ammonia, and by giving the peculiar smell and reactions of its alkali when heated with baryta. Nitric acid has been found in urine, apparently normal.


Urate of Ammonia.

The Fixed Salts, so called from being retained in the ash, are as follows:—Chloride of sodium, which, besides chemical uses elsewhere mentioned, promotes the excretion of the nitrogenous matter. Nearly 200 grs. are daily passed in the urine. *Redtenbacher* found it absent from the urine in 80 cases of pneumonia, and *Dr. Beale* finds it determined to the inflamed lung, to aid in the abundant cell-formation then proceeding, and plentifully thrown off in the urine when the inflammation is resolved. The sputa contained it in one case to the amount of 18 per cent. of solid matter. Its presence is shown by the white precipitate, on adding nitrate of silver. Chloride of potassium is also sparingly present. The sulphates, as of potash, soda, &c., are increased by food, particularly albuminous, which yields its sulphur in this form, or with extractive, and according to *Parkes*, by liquor potassæ. Their amount, as ascertained by precipitation with chloride of barium, corresponds to about 32 grs. of sulphuric acid daily.

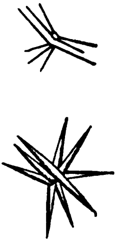
The Phosphates in healthy urine are the phosphates of soda, ammonia-phosphate of soda, phosphate of lime, and ammonia-phosphate of magnesia, which are all tribasic. The daily amount corresponds to about 50 grs.

of phosphoric acid, equivalent to about 120 grs. of phosphatic salts, and about that quantity is contained in ordinary mixed diet. They are derived from the food, some kinds of which contain them largely; peas, for instance, having 9 grs. to the ounce. Some of this is passed in the solid excrement. *Bence Jones* first drew attention to the increase of phosphates which follows increased nervous waste, as by undue mental exertion, or inflammatory disease of the brain or spinal cord. This fact has led to the ready diagnosis of phrenitis and delirium tremens, in which the quantity of phosphates is below the standard, the copious perspiration being perhaps vicarious. Phosphuria is the term applied to that morbid state in which undue quantities of these earthy salts are passed by the kidneys. When occurring as sediment, the phosphates are usually white, but they may be stained by blood. They are insoluble on heating, and may be thrown down from solution on boiling urine, which circumstance might confound them with albumen but that they are dissolved by nitric acid. The precipitation of the earthy phosphates on heating has been explained by the presence of soda, or its tribasic phosphate neutralizing the acid (*Bence Jones*) by carbonic acid being present and evolved by heat (*Brett*), and hydrochlorate of ammonia holding it dissolved (*Owen Rees*). The urine is generally abundant, whey-coloured, of low specific gravity, and usually alkaline, but it may be acid when first passed. The magnesian phosphates form beautiful crystals of prismatic, penniform, or stellate shapes. Phosphate of lime does not occur in the crystalline form, but a copious sediment has been found in mollities ossium. Its amount is de-



Phosphates.

creased during pregnancy and dentition. The excess of phosphates is usually an indication of diseased nervous system, as exhausted, overworked, or softened brain, or injury of spinal cord. *Dr. Graves* found this condition, as well as ammoniacal reaction, in typhus, and a similar fact is related of mania. Blows or sprains upon the back is also a frequent exciting cause. Mere retention of urine will not lead to the liberation of ammonia and deposit of phosphates, if the innervation of the bladder be normal; but in cerebral, or still oftener, spinal lesion, urea undergoes decomposition (the mucus, perhaps, as suggested by *Dumas*, acting as a ferment), and by taking two equivalents of water becomes carbonate of ammonia. This in its turn decomposes the phosphates, throwing down the earthy salts and carbonate of lime. An abundance of stringy or ropy mucus is found in the urine in these cases, the result of the irritation to the mucous surface. It has been lately advanced that this tenacious material is pus, acted on by ammonia, which, as well as other alkalies, has the effect of converting that fluid into a sticky, gelatinous mass. The urine is alkaline from ammonia when the disease is local, and from the fixed alkalies when general nervous disorder exists, a diagnosis which can be therefore made by the temporary or premanent action on litmus paper. The following remarks of *Golding Bird* are most valuable :—" Where the presence of a deposit of phosphates is independent of the irritation of a calculus or of organic disease, it is most abundant in the urine passed in the evening (urine of digestion), and absent or replaced by uric acid or urates in the morning (urine of the blood), the urine being always of a tolerably natural colour, never below and often above the mean density. Where the presence of phosphatic salts depends on the irritation of a calculus, or of organic mischief in the urinary passages, the urine is pale and whey-like, of a density below the average, often considerably so, and the earthy deposit is nearly equally abundant in the night and morning urine." In the most numerous cases, or those connected with dyspepsia, the administration of tonics, as sulphate of zinc, strychnia, and attention to the condition of the digestive and nervous functions, are the chief curative indications. Opiates and mineral acids, serve those cases dependent on spinal lesion, while *Bird* mainly relied on injections of either plain tepid water, or with a few drops of nitric or hydrochloric acid in those cases, which, being connected with chronic inflamed bladder, he terms "phosphatic cystitis."


Carbonate of Soda.

Carbonate of soda, is occasionally found in the urine, producing a permanent effect on litmus. It occurs copiously after the ingestion of salts of organic acids, as tartrates, nitrates, &c., carbonic acid resulting from their decomposition. Its crystalline form is peculiar.

Carbonate of lime, as before mentioned, is often deposited in phosphuria. It occurs frequently among the herbivora, forming beautiful little bodies identical with pearls.

To illustrate the variations which the normal constituents of the urine may undergo in disease, I quote the following table from *Dr. Parkes*, which shows the effect of rheumatic fever on that secretion, and the influence of an important medicine:

		Effect of Liquor Potassæ.
Solids	increased	still more increased.
Water	greatly diminished	slightly increased.
Uric acid	increased	slightly increased.
Sulphur	in considerable quantity	probably increased.
Chlorine	diminished	unaffected.
Sulphuric acid.	greatly increased	still more increased.

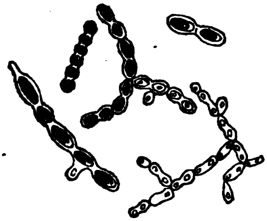
The same analyst gives the following quantities of solid urinary ingredients, which he found excreted by a patient during a paroxysm of gout in the 24 hours: urea, 322·3 grs.; sulphuric acid, 24·75; phosphuric acid, 9·5.

Having now mentioned the normal constituents of the urine, and the circumstances in health and disease which increase or decrease their proportion, we shall next consider some abnormal states of the urine, which may be arranged under three heads: 1. Dissolved abnormal matters; 2. Sediments; 3. Calculi.

I. **Bile**, as before alluded to, may stain any of the secretions when its separation from the blood or discharge into the alimentary canal is prevented. Urine containing it has a deep brown colour, and, if shaken, its foam will be coloured yellow. It is merely the bile-pigment which stains the urine in jaundice, but *Heller* has found bilin in cases "where tuberculosis and nutmeg liver co-exist." The presence of bile in urine is often of great diagnostic value, for instance, in cases of abdominal dropsy it shows if it be of hepatic origin. The tests for bile have been mentioned at page 172.

Sugar was discovered in urine by *Willis* about 1674, and is sometimes found in great quantity, forming 50 to 80 or, in one case, 134 in 1000, so that over 1¼℔ may be daily excreted. Such urine is of a specific gravity ranging from 1·030 in 1·060, and yet of pale color, being the only condition which produces dense, yet light-coloured urine. Its amount is usually great, 10 or 12 pints is a frequent amount, and 52℔ have been excreted in one case in 24 hours. Although clear when passed it soon becomes turbid, owing to fermentation. The odor is fragrant, like apples or new-mown hay, and the taste sweet. Patients often remark that it attracts flies. Diabetic sugar, which is identical with glycose, may be separated by carefully evaporating the urine and digesting it in alcohol. White crystalline masses then separate spontaneously. It is harder, less soluble, and less sweet than cane sugar, and also differs in dissolving in sulphuric acid, which forms a bulky charred mass with cane sugar. Besides *Moore's*, *Trommer's*, *Maumene's*, and the fermentation tests described at page 39, some others may be mentioned, as well suited for its detection in urine. *Fehling* and other German chemists advise the following solution to be used after *Trommer's* method: 1 oz. of sulphate of copper, 3 ozs. cream of tarter, 1½ oz. carbonate of potash, 14 ozs. of solution of caustic soda, and water till the whole measures 15,160 grains. As the copper in 200 grs. of this fluid is reduced by one grain of sugar, it affords an admirable means of quantitative analysis. *Barreswil's* fluid contains cream of tartar, carbonate of soda, of each 96 grs.; sulphate of copper, 32 grs.; caustic potash, 32 grs. to 2 oz. of water. *Horsley's* fluid is an alkaline solution of chromate of potash, which, if boiled with diabetic urine, produces a deep sap-green colour. Diabetic urine also decolorizes tincture of iodine, and if shaken with chloroform, the sugar will separate in an upper stratum. The polariscope has been applied for the detection of sugar by *Bouchardat*, and *Prof. Jellett, T.C.D.*, has arranged a more available form of that instrument, which he terms the "saccharometer." Cane sugar does not give the same reactions as diabetic sugar, into which it is, however, converted by a little nitric or sulphuric acid, as they yield oxygen.

The torula cerevisiæ, or yeast plant, which is so characteristic of saccharine urine, when undergoing fermentation, is here figured. A number of mistakes have arisen by using, in *Maumene's* test, cotton or linen cloth, as its cellulose gives the same reaction as sugar.



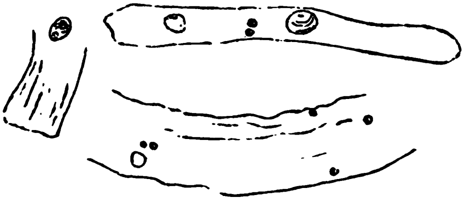
Torula Cerevisiæ, or Yeast Plant.

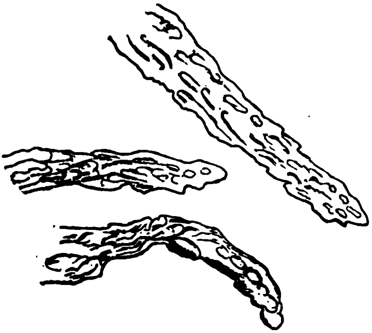
The glycogenic function of the liver has been already alluded to, and the effect of irritation of the floor of the 4th ventricle in producing sugar in the urine. We have noticed *Brücke's* assertion, confirmed by *Pavy*, that sugar is a normal constituent, and can be discovered by the bismuth test. About 2 grs. can be obtained from 1000 cubic centimetres of healthy urine. It was also stated that the liver had the power of converting cane sugar into glycose, and that it was in the lungs the sugar was destroyed, a very small quantity remaining in the arterial blood, and undergoing decomposition in the systemic capillaries. Experiments have shown that sugar is destroyed in proportion to the efficiency of the following conditions: 1. Due supply of oxygen; 2. Presence of disintegrating albuminoid body, especially fibrin, for if defibrinated blood be charged with sugar, it passes through the lungs of an animal without loss of that substance; and, 3. Presence of an alkali in the blood. From such considerations it appears, that diabetes may result from deficient oxidation of the un-nitrogenized matters, as gout does from the nitrogenized matters being only oxidized as far as the condition of uric acid. It has been stated that the urine of old people contains sugar as the respiratory function becomes impaired, and it is said to occur in the urine of suckling children.

In Diabetes we cannot as yet with confidence assign the fault to any one organ. In the earlier days of pathology, the kidney was believed to be the organ diseased; but this gland merely strains the sugar from the blood. The stomach, where saccharised starch is absorbed—the liver, where glycose is generated or cane sugar changed into it—the lungs, where the sugar should undergo combustive destruction—and the nervous system, which regulates these other functions, have been all severally accused of being the seat of the ailment. In some cases, only as much sugar is passed as can be accounted for by the amount of sugar or starch ingested. Such cases are most remediable: thus, the late *Mr. Camplin* informed us that he resisted the disease for 10 years by excluding such substances from his diet, which mainly consisted of bran cakes. The amount of urea passed in 24 hours is not decreased, although its proportion in any specimen may be less. *Sir R. Kane* found one specimen of diabetic urine, sp. gr. 1·036, to contain water, 913; sugar, 60; urea, 6·5; salts, extractive, and uric acid, 20·5. Diabetic urine has occasionally a low sp. gr.—thus, in a case of *Dr. Owens'*, *Dr. Cameron*, the City Analyst, found sugar although the sp. gr. was but 1·015. Diabetes is frequently combined with pulmonary phthisis, which then is usually the immediate cause of death. The latter disease supplies the condition of blood surcharged with cacoplastic fibrin which, according to some, undergoes actual conversion into sugar. We shall afterwards discuss the question whether tubercle be the result of excessive or deficient oxygenation, but the fact that so highly oxidisable a material is so abundantly excreted in these combined cases, lends support to the latter theory. Inosite, or muscle-sugar, would seem sometimes to replace grape-sugar in diabetes, as in a case of that disease 300 grains were daily excreted.

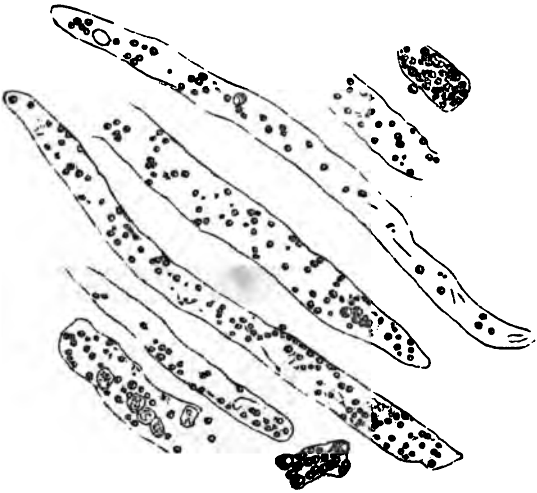
Albumen must be regarded as abnormal in the urine, save in that of the fœtus, in which *Dr. W. D. Moore* has found it in 8 specimens examined. The urea was hardly to be found, and, owing to the great activity of the liver and absence of respiration, sugar is also usually present. Albuminous urine has generally a low specific gravity (1·010 to 1·005), due to the absence of urea, not to the presence of albumen; for when both concur, as in some acute inflammations, the density of the fluid is over the normal standard. It cannot be distinguished by any peculiar colour, reaction, or smell, but is said to putrify faster than healthy urine, and appears to contain carbonate of ammonia, as it often effervesces with nitric acid. The quantity present may range from a trace to 12, 20, or even 30 parts in 1000. Two tests are reliable if used conjointly. Heating to 160° or over, according to the scarcity of the albumen present, produces a flocculent white cloud soluble in alkalies and the weaker acids. The objections to this are that it will not precipitate if the urine is alkaline, or if the albumen be of the soluble kind which *Dr. Prout* states occurs in chyle, and that heat throws down a very similar cloud if earthy phosphates are in excess, but this latter disappears if a drop of nitric or any other acid is added.

Nitric acid (or, as *Bird* recommends, nitro-hydrochloric, as it contains free chlorine) precipitates albumen, producing almost a solid mass if it be abundantly present, or a slight flakiness if it be in small quantity. The objections are that in highly concentrated urine, uric acid


Waxy Casts from the Uriniferous Tubes.

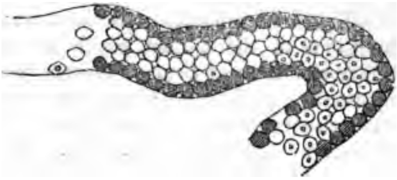

Epithelial Casts.

is occasionally thrown drown by nitric acid; and a whitish cloud is said to appear if the patient be taking resinous substances, as copaiba, cubebs, &c. Heat does not produce such effects, so any white cloud precipitated by heat and nitric acid may be regarded as albumen. Bichloride of mercury, ferrocyanide of potassium (acetic acid being first added, as the precipitate does not appear in an alkaline solution), creosote, tannin, have been also used for detecting albumen in urine. Tannin will, however, throw down a copious precipitate of tanno-gelatin, if soup had been partaken of shortly before. As *Bence Jones* discovered, a drop or two of nitric acid may render albumen soluble even in boiling urine, but a little more of the acid will throw it down coagulated. Space will not allow us to discuss at large the pathology of albuminuria, but it may be noticed that that condition of



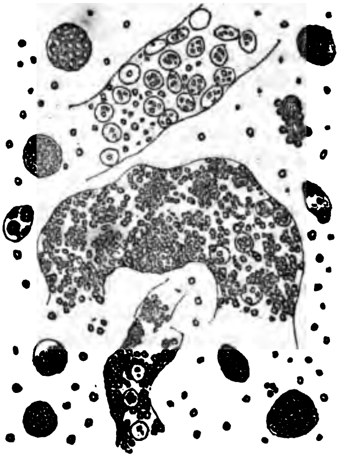
Oily Casts from the Uriniferous Tubes.

the urine is not pathognomonic of *Bright's* disease. *Dr. Parkes* has found temporary albuminuria in paraplegia, hemiplegia, phthisis, bronchitis, pneumonia, heart diseases, acute and subacute rheumatism, typhoid and typhus fevers, variola, scarlatina, and erysipelas, and permanent albuminuria in encephaloid and cystic disease of the kidney, leucocythemia, heart diseases, &c., as well as in *Bright's* disease. The presence of albumen, however, in any considerable quantity, and persistent, is sufficiently serious to warrant medical officers of insurance companies in rejecting individuals in whose urine it has been discovered.



Healthy Uriniferous Tube.

Casts of the uriniferous tubes are much more surely indicative of *Bright's* disease than the presence of albumen. The varieties of these objects are described and named most accurately by *Dr. George Johnson* as follows: Epithelial casts,



Uriniferous Tubes filled with oil.

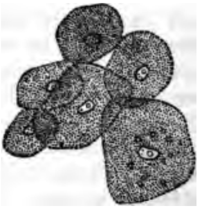
small waxy casts, large waxy casts, granular casts, oily casts, bloody casts, purulent. We have here exhibited the microscopic appearance of the first five kinds, from cases which occurred in *Mr. Richardson's* practice. The figures on the foregoing page represent a healthy tubule and one filled with fat globules. *Johnson* arranges the morbid conditions of the kidney, which are often confounded under the term of *Bright's* disease, as follows: Acute desquamative nephritis, chronic desquamative nephritis, waxy degeneration, non-desquamative disease, fatty degeneration, suppurative nephritis. He believes the occurrence of dropsy is due to the remora in the renal circulation; whereas *Becquerel*, with, I think, more reason, attributes it to the thinness of the blood, for the albumen, escaping in the urine, does not preserve its proportion of 7 per cent.

II. **Sediments** are either (1) organised, or (2) saline.

1. **Blood** in the urine appears as a flaky, dark red cloud, mixing with the fluid by agitation, and again subsiding by rest. Chemical tests are not reliable, except as showing the albumen present; but the microscope exhibits the well-known form of the blood-cells, somewhat altered if they have lain long in the fluid. Besides hematuria, when the blood is derived from the kidney and mixed with urine, blood may be poured from the bladder, when it generally flows after the urine has been just passed—or from the urethra, when it precedes the urine, or oozes out at other times besides micturition.

Pus generally appears as a greenish-yellow cloud, mixing if the urine be shaken, and subsiding afterwards. The urine is frequently acid, but, if alkaline, forms a gelatinous transparent mass, like thick mucilage, which character, on adding ammonia or liquor potassæ, affords clear evidence of purulent deposit. The supernatant liquid contains albumen.

Mucus may be distinguished by occurring in alkaline urine, in not yielding fat to ether, which pus always does, and in not being albuminous. Leucorrhœal discharges appear somewhat similar; but between epithelial cells, discharged in these cases, and pus cells, the microscope will establish a ready diagnosis. The occurrence of epithelial cells has been referred to when speaking of albuminuria, and those from the vagina are here represented. Ordinary mucus cells and pus cells are identical, according to *Virchow*.

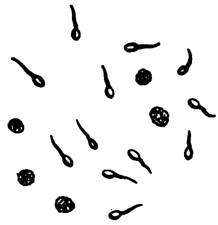


Epithelial Cells from Vagina.

The pus may be derived from abscesses finding exit by the urinary passages, for, as *Hunter* remarked, they always tend to a mucous or cutaneous surface. Even such remote collections as empyema, or those due to carious vertebræ, may thus escape, and many of the so-called vicarious discharges of pus may be in this way accounted for. There are, however, some reported cases where there could be no communication, save through the general circulation, and yet where purulent urine seemed to follow the disappearance of abscesses. The improbability of such an event will be discussed in treating of blood diseases. Very often pus in urine is due to pyelitis, ulcerated bladder, strumous disease of prostrate, urethral disease, &c. Pus was passed to the amount of 6 ozs. daily for many weeks, in a case of tubercular disease of the prostrate I lately attended.

Fat, as before stated, often occurs in the tubular casts of chronic *Bright's* disease, as can be only discovered by the microscope; but it may be so abundant as to be evident to the eye, or by chemical tests in "chylous urine," first described by *Dr. Prout*. The fat can be readily separated by ether, and has amounted to 20 parts in 1,000. The fibrin which is generally present produces coagulation of the fluid into a mass aptly compared to blancmange. The fat rarely occurs in globules, but seems emulsified through the whole fluid. It may occur to the amount of 13 per 1,000 in one specimen, and be entirely absent from that passed a few hours afterwards. The condition has been chiefly found in persons with a tendency to obesity, but may be a precursor of *Bright's* disease, and in Demerara has occurred as an epidemic, attended with much emaciation. Gallic acid is the most successful remedy. Fat is said to have been found in the urine in cases of rickets, and in that of insane persons.

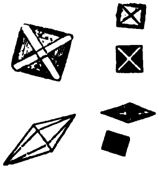
Spermatozoa can be occasionally found by microscopic examination, which affords the only evidence of their presence, in the lowest portion of adult male's urine. They are usually mixed with seminal granules, and with crystals of oxalate of lime, which *Donné* incorrectly states are never found save in spermatic urine. The presence of spermatozoa in the urine of a female after coition, has afforded valuable medico-legal evidence. If occurring in the urine of men, they cannot be said to always indicate disease, as some seminal fluid frequently remains in the urethra or vesiculæ after an emission, and is subsequently passed with the urine, or forced out along with prostatic mucus by hardened fæces during defæcation. Cases of spermatorrhœa, as they are called, are nearly always imaginary complaints, suggested to the minds of hypochondriacal and enervated young men by those demoralising and disgusting advertisements which the authorities should have, long since, suppressed.



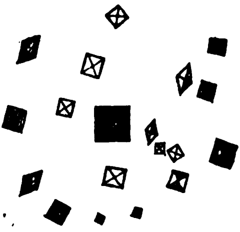
Spermatozoa and Seminal Granules.

Besides those vegetable growths which we have seen occur in saccharine urine, penicillium glaucum and other confervoids have been found, but they have no constant connexion with the cause of typhus, cholera, and other diseases, as once believed. Vibriones also have been discovered in the urine of cachectic subjects some time after being voided, but are probably but products of decomposition. Sarcina ventriculi (discovered by *Goodsir* in the matter ejected from the stomach in pyrosis) has been found in the urine, especially in spinal diseases. The trichomonas vaginæ may be found occasionally in women's urine. 2. The only saline or crystalline sediment which here requires description, is oxalate of lime, as several other deposits, consisting of excess of the normal salts, have been already alluded to.

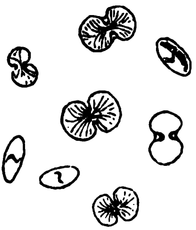
Oxaluria, or that diathesis in which oxalate of lime is deposited, was first described by *Golding Bird*, who asserts that it is a more frequent morbid deposit than the earthy phosphates, whereas *Lehmann*, *Bence Jones*, and *Owen Rees* deny it a place amongst urinary diseases. The salt is diffused through the urine, and from similarity of colour may escape detection, but is never dissolved, and has usually the crystalline form of transparent, sharply-defined octohedra, as here figured. Their composition is shown by ignition,



Octohedral Oxalate of Lime.



Octohedral Crystals.



Dumb-bell Crystals.

leaving carbonate of lime, which will effervesce with nitric acid. The second woodcut represents crystals of a dumb-bell shape, which often concur with the octohedral variety; but, from their different action on polarized light, *Dr. Bird* regarded them as oxalurate of lime. Oxaluric acid ($C_6 H_3 H_2 O_7 HO$) differs from oxalic acid in the elements of urea being substituted in the former for those of water in the latter. *Beale* states the dumb-bells are also oxalate of lime. The urine has no very striking peculiarities, save that the urea and other nitrogenized matters are usually above average, which accounts for its rather high specific gravity and for the emaciation of the patient. It is generally acid. Epithelial scales are often abundantly present. With regard to the pathological source of oxalic acid, *Dr. Aldridge* has stated that urine may normally contain some substance analogous to sugar, which may undergo acetous fermentation; but from the rarity of sugar and oxalates in the same urine, it has been doubted that the acid is derived from sugar or other unnitrogenized matters. *Dr. Bird* supposed it to be due to a re-arrangement of the elements of urea, producing oxalate of lime in the blood, where *Dr. Garrod* has found it. He appeals to the ready conversion of urate of ammonia, in the guano of South America, into oxalate of ammonia, which often occurs before it reaches this country. *Liebig* believes that it is uric acid, and not urea, which produces oxalic acid; for uric acid, by the use of an oxidising agent, as peroxide of lead, is convertible into oxalic acid, urea, and allantoin. It appears to be derived from nitrogenized food rather than nitrogenized tissues. Many vegetables, as rhubarb, sorrel, &c., contain oxalate of lime, which will be found in the urine if they are ingested. In such plants its crystals are contained in the vegetable cell, and in man it has been found in crystals in epithelial cells.

Bird divided cases of oxaluria into (1) those with excess of urea and extractive; and (2) those without such excess.—1. In some cases throughout, and in all the earlier stages, the symptoms are slight and the general health is but little interfered with. Low spirits, melancholy aspect, and dingy hue of face, nervous susceptibility, irritable temper, dyspeptic feelings, emaciation, loss of virile power, pain or sense of weight in the loins, and the eruption of minute boils, are some of the symptoms which attend this form of the disease in more aggravated cases. The 2nd class of cases are often connected with dyspepsia and over-wrought brain, and has been found very frequently, with the accompaniment of irritable bladders, in members of the legal profession. Chronic diseases of the respiratory organs also often produce oxaluria; the oxidation of the carbon, as *Lehmann* suggests, being thrown upon the kidney, and oxalic acid (C_2O_3) being formed instead of carbonic acid (CO_2). Nitric and nitro-hydrochloric acids, sulphate of zinc, iron, colchicum, due proportion of vegetable food, and attention to the action of the skin, are the chief curative agents, and they have proved very successful.

III. **Calculi** are very various, but may be identified by physical and blowpipe characters, which are here tabulated:

Composition.	Size and Form.	Colour and Density.
URIC ACID. $C_{10} H_4 N_4 O_6$	Large; ovoid, having facettes when numerous.	Reddish brown; dense, frangible, sp. gr. about 1·500.
URATE OF AMMONIA. $NH_4 O, C_{10} H_4 N_4 O_6$	Small; spheroid.	Clay or slate-colored; sp. gr. about 1·475.
CYSTIN. $C_6 H_6 NO_4 S_2$	Moderate; oval oblong.	Greenish or tawny yellow; waxy consistence.
XANTHIN. $C_5 H_2 N_2 O_2$	Moderate; ovoid.	Cinnamon-colored; hard.
UROSTEALITH.	Moderate; ovoid.	Dark brown; elastic, or soft and waxy.
PHOSPHATE OF LIME. $8 Ca. O, 3 PO_5$	Moderate; spheroid.	Greyish white or brown; compact.
TRIPLE PHOSPHATE. $2 Mg O, NH_4 O, HO PO_5$	Large; ovoid.	Nearly white; friable.
FUSIBLE. Mixture of two preceding.	Very large; irregular.	Quite white; leaves chalky streak; sp. gr. about 1·300.
OXALATE OF LIME. $Ca. O, C_2 O_3$	Moderate; spheroid.	Brown, olive green, or purplish; very dense, sp. gr. about 1·700.

Surface.				Blowpipe Characters.
External.	Internal.	Fracture.		
Smooth.	Polished; concentric.	Crystalline.	Combustible.	With odour of burnt bone and hydrocyanic acid.
Finely tubercular.	Thin concentric layers.	Earthy.		With ammoniacal odour, and decrepitating
Tubercular or sharp projections	Radiated.	Lustrous.		With odour of sulphuret of carbon, and blue faint flame.
Resinous lustre when rubbed.	Laminated.	Brown and white mixed.		With peculiar fetid odour; splits into fragments.
				With odour of perfumed shell-lac, and bright yellow flame, and leaving voluminous coal.
Porcellaneous.	Laminæ easily separated.	Conchoidal.	Incombustible.	Fuses by intense heat, residue not alkaline, soluble in nitric or hydrochloric acids.
Uneven—studded with crystals.	Crystalline or earthy.	Crystalline or earthy.		Fuses with difficulty, evolving ammonia, residue not alkaline, soluble in nitric or hydrochloric acids.
Rough, spongy.	Indistinct layers.	Earthy.		Fuses readily into a white bead.
Rugged, spinous, mulberry-like.	Laminæ like agate or fortification; polished.	Splintery.		Infusible, blackens, expands; white residue, soluble in acids with effervescence, or after strong ignition without effervescence, but alkaline.

Many of the chemical features of the substances which compose these calculi have been before described. Their relative frequency is shown by *Dr. Bird's* catalogue of those in Guy's Hospital. In 353, of which sections and analyses were made, the nucleus was composed of uric acid, 250; oxalate of lime, 47; urates, 19; fusible, 19; cystin, 11; phosphate of lime, 2; xanthin, 1; triple phosphate, 1; and 3 were mixed without lamination. A still rarer calculus, urostealith, was discovered by *Heller;* and *Dr. W. D. Moore* has examined the only other specimens which have been found. They occurred in a patient of *Mr. Robert Adams'*. In *Heller's* case treatment was very successful, carbonate of soda having wrought a complete cure, probably by saponifying the fat.

As closely connected with the physiological action of the kidney, and constituting our chief means of cure in its abnormal conditions, a few words on the action of diuretics may not be out of place. Reference may be also made to the chapter on "Absorption." All substances which pass to the kidneys must be absorbed, having been previously in solution, or been dissolved in the alimentary fluids. All solids, however finely divided, and organic particles, as those of pus, are refused admission through the coats of the blood-vessels or lymphatics, which at once absorb fluids, and if placed directly in the blood, cannot be thrown off by the kidneys. The next condition is, that substances should be freely diluted, as, if their specific gravity is over that of the serum of the blood (1·026), according to the law of osmose that fluid will ooze out, instead of the dissolved substance being absorbed. Catharsis, by a large concentrated dose, and diuresis, by a small and diluted quantity of a neutral salt, are thus explained. *Dr. Bird* advises that the proportion of a diuretic salt should be always under 5 per cent. Even with the foregoing conditions complied with, there are some bodies which do not pass into urine, but select some other surface for elimination—such are alcohol, ether, &c.

Other substances undergo chemical change—thus, ferrid-cyanide of potassium appears as ferrocyanide, tannic acid as gallic, benzoic and cinnamic acids as hippuric, and the salts of the vegetable acids, citrates, acetates, tartrates, &c., are converted into carbonates—a fact we often take advantage of when, in treating disease, we wish to render the urine alkaline. Thein, and some such nitrogenous bodies, appear as urea; whereas quinine, daturine, and some others, pass unchanged. *Dr. Bird* cites, as a good example of a poison passing directly into the urine, the amanita muscaria—so that a number of men produce intoxication by taking this fungus, and again produce the same effect by drinking the urine into which the poison has passed. Many colouring matters—as those of maddar, beetroot, logwood, bilberries, rhubarb, and senna—pass into urine, staining it a red colour, the two latter being especially apt to be mistaken for blood, but distinguished by turning yellow when sulphuric acid is poured into urine containing them; whereas blood becomes of a brown colour. Urea is said to be highly diuretic, and has been administered with such object, yet it is retained in the blood in cases when the uriniferous tubes are obstructed. The action of diuretics is much controlled by the state of the skin, so that by keeping its temperature low, or raising its heat, we have the power of aiding or checking their power, and of making a dose of a given substance act as a diuretic or diaphoretic.

Dr. Barlow has stated the remarkable fact, that if there be any obstruction in the course of the bowels, the amount of urine will be lessened in proportion to the distance of the obstruction from the pylorus, thus giving some diagnostic aid in fixing its exact situation. Any obstructive disease affecting the circulation between the vena porta, by which diuretics are absorbed, and the renal artery, from which they are excreted, will hinder their action. The expediency of combining mercury to stimulate and relieve engorgement of the liver, and digitalis to control cardiac action, with diuretics, such as squills, has been always acknowledged since *Dr. Baillie's* time, and is explained on the above principle. From some recent experiments it would appear that colchicum is almost the only drug which materially increases the solids of the urine, broom, squills, water (which is a diuretic not to be despised) merely increasing the amount of water. The alkalies and their salts, with vegetable acids, may be looked on as "renal depurants," as they produce and excrete in increased quantity nitrogenized matters. Their condition of "nascent carbonate," when the vegetable salt is being decomposed, seems to augment their chemical power. From such considerations may be strongly advised the administration of acetate, tartrate, or citrate of potash in ague, acute rheumatism, and some other blood diseases. Impressed with its high oxidising power I have depended more on chlorate of potash—(*Medical Press, Feb.*, 1864.)

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. How would you know any given fluid was urine?
2. How much urine is passed daily, and what is the amount of its largest solid constituent?
3. Say what you know of urea.
4. Describe the physical characters of diabetic urine, and the effects of yeast upon it.
5. What are the usual organized sediments found in urine?
6. Arrange urinary calculi in the order of their frequency, mentioning any chemical or physical characters of each you may remember.

SENIOR.

1. To what has the acidity of urine been attributed? What normal circumstances alter the characters of that secretion?
2. What are the nitrogenous and the fixed saline matters in urine?

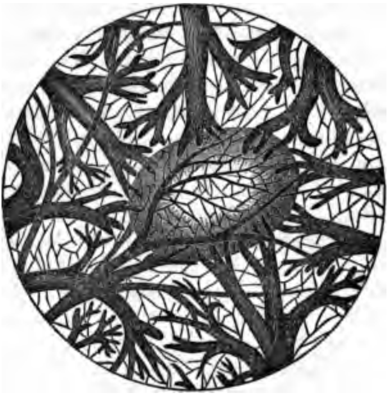
3. What diseases alter the quantity of urea excreted?
4. Describe fully the methods of conducting two of the most accurate tests for sugar in urine.
5. Compare the various casts which are found in abnormal urine.
6. Describe the microscopical features of the sediment which occurs in oxaluria.

THE DUCTLESS GLANDS.

THE ductless glands may be here conveniently described, as they have most relation to the great function of nutrition. They are the spleen, suprarenal capsules, thymus, thyroid, and perhaps the pineal, pituitary, and Pacchionian bodies. They agree in the absence of any excretory duct, in being composed of cells, and in being copiously supplied by blood, the composition of which they seem to influence; hence they are often called vascular glands.

The Spleen is an oval, smooth, dark-red body of a most variable size, decreasing to one-half in old age, and changing with the state of the nutritive and digestive functions, being largest 12 hours after feeding, according to *Gray*. The peritoneum, continued from the stomach round vessels, envelops it very completely, but is often wrinkled when the organ is shrunken. There is also a firm, yet distensible fibrous capsule, showing no muscular tissue in man, but it may be seen in many animals, as dog, cat, pig, ass, &c. In most herbivora it is elastic, not muscular. This capsule dips in at the hilus, ensheathing the vessels like the vaginal processes of *Glisson's* capsule, and forming trabeculæ, which intersect the organ into spaces opening freely into each other. The trabeculæ are felt if the finger is thrust into the friable interior, or are well seen by washing the substance thoroughly. The muscular tissue in the trabeculæ of some animals cannot be stimulated by galvanism.

The soft matter which fills the interior is called the pulp. It contains very many cells, like the white blood cells, but very variable in size and number, according to the quantity and quality of food previously taken. Red blood-cells are also present, giving the spleen its colour, but they are irregular, shrunken, or disintegrated, and several are sometimes grouped together by an investing membrane, and afterwards dissolved. In the fresh spleen of man, many mammals, birds, and some reptiles, there are oval corpuscles, named Malpighian from their discoverer. They are about $\frac{1}{60}$ in diameter, and contain many small cells, and an occasional blood-cell. Other blood-cells occur in the parenchyma, cluster together in a peculiar manner, or which are merely those of stagnated blood, according to *Sanders*. The Malpighian corpuscles lie in the divisions of small arteries, which send capillaries as a plexus round them, or into their interior, as in *Peyer's* glands, observed by *Busk* and *Sanders*. There is one in about every cubic line of the spleen, but they increase much in number and size after a full diet, especially if albuminous.



One of the Spleen Cells, showing its relation to blood vessels.

The splenic artery is larger in proportion to the size of its organ than any other, save the thyroids. It bifurcates so freely as to produce a tuft like, as *Müller* said, a camel-hair pencil, but branched more like the umbel of aniseed or hemlock. The vein is still larger, and the spleen can be more readily injected from it, valves being absent. It joins the mesenteric veins, and so forms the porta. *Gray* found its radicles to begin—(1) by capillaries; (2) as a vascular capsule round the Malpighian bodies; and (3) in the interspaces between the trabeculæ. These vessels and a Malpighian cell are depicted on the foregoing page. Its blood differs from other blood in having much less solid matter—even but half the quantity of cells; but *Gray* states the albumen and fibrin are increased. The serum has often a reddish tinge.

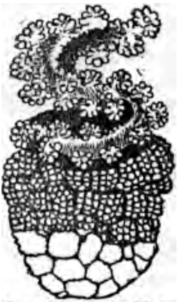
The use of the Spleen is not yet positively determined. From its spongy distensible nature, its increase during digestion, and in diseases where the cutaneous or other circulation is diminished, as in ague and cirrhosis of liver, and gradual decrease during hematemesis, it has been regarded as a temporary reservoir or diverticulum for the blood of the chylo-poietic viscera, as suggested by *Stukely*. It has been found to weigh 20 ℔ in ague. From the shrunken state of the blood-cells, *Kölliker* stated, in 1847, that they were broken up and destroyed after being clustered in groups. In 1854, however, he acknowledged that he could not regard this as the normal or exclusive function of the spleen, as he found such cells in the liver and peritoneum of fishes, and in clots of effused blood, and they cannot be seen at all in many animals. Their hæmatin was supposed to be discharged as the colouring matter of the bile, which, however, appears in the chick before the splenic vessels are discernable. The diminution of the red cells in the splenic vein favoured this theory. *Hewson* long ago believed that the spleen, with the aid of thymus, made the blood-cells, and the opinion is supported by *Virchow* and

Hughes Bennett. Its blood-making function is probable from the great quantity it receives, and its free supply round the Malpighian bodies, where some active cell-change is going on. They cannot purify the blood by removing any hurtful matter, nor make any useful secretion, as no excretory duct, even a lymphatic, has been found leading from them. Whatever these bodies elaborate is thrown into the circulation. It is remarkable that *Malpighi* shadowed forth these opinions when he called the corpuscles he discovered secreting glands. *Gray* regards the organ as regulating the quantity as well as quality of the circulating fluid. From the superabundance of albuminous over fatty or hydro-carbonaceous material, it seems to have little connexion with the respiratory function. In leucæmia we shall find that the spleen or thyroid is much hypertrophied, another fact supporting the above view. The spleen receives albumen freely from the stomach during digestion.

Tying the porta has been said to increase the spleen 10 times. The organ has been often removed from animals, when, if fed freely, they are said to die of apoplexy. Their appetite is said to become awfully ravenous, and their temper most irritable and ferocious. It was stated that rabbits, rendered tuberculous by confinement in close, dark places, were restored to health after extirpating the spleen. I must mention, however, that the white specks found in the lungs of cooped animals, are said by some microscopists to be cysticerci. If they be tubercle or any other product of white cells, the experiment I have mentioned explains the function of the spleen. Animals will live after removal of the spleen, both the suprarenals and the thyroid.

The Suprarenal Capsules are shaped like cocked-hats, and lie in areolar tissue above the kidneys. They are formed beside the Wolffian bodies, and increase for about a year after birth. A section shows a cortical structure, very vascular, and composed of large cells, separated by septa sent in from the fibrous covering, and a medullary portion made up of areolar tissue, and many pale cells, some like those of grey neurine. A cavity filled with brownish, grumous matter often exists. The suprarenal body is supplied by many filaments of the sympathetic and pneumogastric nerves, *Kölliker* having counted 33 entering into one. From this fact it has been supposed these bodies have some nervous function, the only guess made as to their use. Injury of the dorsal portion of the spinal cord congests and hypertrophies these bodies. There has been discovered in the watery solution of their cortex a substance of a lovely rose tint, which turns green with per-salts of iron ; and leucin also exists. *Addison* maintained that a brown colour of the skin often accompanies morbid alterations of these organs.

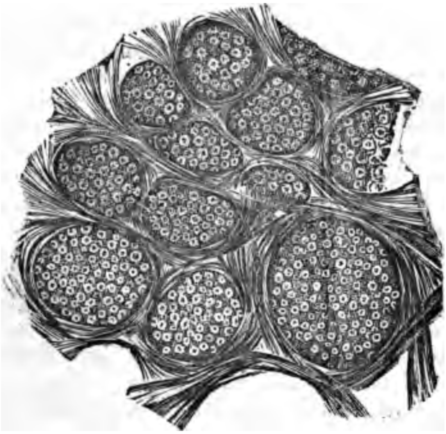
The Thymus has often been supposed to be connected in some way with the last-described bodies, as they occur about the same period of life. It has two lobes, which lie in the anterior mediastinum, rising often into the neck. Its arteries are large, and the veins form a plexus, in common with those of the thyroid, in front of the trachea. Its very abundant lymphatics open into the cava, and convey into the blood the numerous white-cells the gland is constantly generating. *Sir A. Cooper* and *Simon* have shown that it consists of a duct much convoluted and branched, and cells filled with a finely granular matter. *Simon* thinks this body forms some protein compound, and calls it "a sinking fund in the service of respiration ;" but when other glands appear it diminishes, and disappears between the 8th and 12th years, or continuing till the 20th, according to *Kölliker*. It has been found almost entirely wasted in over-driven lambs.



One of the Lateral Lobes of the Thymus, with its upper portion unrolled.

The fact of an enormous fatty mass, probably the thymus, being developed behind the sternum of hybernating animals just before the torpid state, has induced some to connect this body with the calorific function. It can have no relation to lactation, as it is found in birds and reptiles. Animals are said to become very voracious when it is extirpated.

The Thyroid is an extremely vascular body, its arteries being nearly as large as those of the brain, which is 30 times its weight. It consists of two lobes, joined by an isthmus across the 2nd, 3rd, and 4th rings of trachea, occasionally behind them, or sometimes entirely absent. It has a fibrous capsule, and some muscular fibres from the sterno-thyroid, which *Soemmering* named the "levator glandulæ thyroidei." As above figured, the thyroid is composed of shut cells or vesicles, between $\frac{1}{35}$ and $\frac{1}{200}$ in diameter, grouped into lobules connected by areolar tissue. The vesicles have a structureless wall, lined by



Cells, Lobules, and Areolar Trabeculæ of Thyroid.

epithelial cells, and contain a yellowish, viscid, and highly albuminous fluid. In goitre, the most common pathological state of this body, the cells are enlarged and contain a colloid substance. *Beale* gives the following analysis of the whole mass:

Water	70·60
Albuminous and fatty matter	26·384
Extractive	1·70
Salts	1·316

The thyroid is somewhat relatively larger in fœtal life. *Simon* assigns as a use that it may act as a diverticulum to the cerebral circulation, holding the materials of nutrition for the brain during its inactive state, its size increasing much during sleep. This view is rather improbable, as the arteries do not come from those going to the brain, but from the external carotid and thyroid axis of subclavian, after giving off the vertebral. The fullness of the cranial circulation and prominence of the eye-balls, as noticed by *Graves*, *Stokes*, and others, in cases of goitre, hence called exophthalmic, support this theory. *Dr. Stokes* states the enlargement is due to increased power of the heart sending more blood into the thyroid, and the prominence of the eye-balls, which is sometimes so great that the patient sleeps with the eye-balls thrust out between the lids, to increase of the aqueous and vitreous humours. *Sir A. Carlisle* believed its function was to keep an equable heat about the larynx—hence its hypertrophy in cold climates. It was also once regarded as a sounding-board for the larynx; but, as a most intelligent late pupil of mine, *Dr. Floyd*, suggests, it would rather muffle the voice, and prevent its loss towards the chest. The gland is large in females, especially if the catamenia are deficient; and its hypertrophied condition, bronchocele, has been assigned to many circumstances, such as soil, climate, food, drink, &c.—as I have mentioned in my "Lectures on Public Health."

The Pineal Gland is placed amidst nervous masses, and seems to have some resemblance to them. It consists of tubules, nucleated vesicles, and brain sand, composed of phosphate and carbonate of lime, which is not developed till seven years of age. The habenæ are thought to establish some nervous connexion, but we are as ignorant of its use as when *Descartes* guessed it to be the seat of the soul.

The Pituitary Body is composed of gland-like vesicles and abundant capillaries. *Luschka* believes it quite analogous to a structure he has discovered at the other extremity of the cranio-spinal axis, "the coccygeal gland;" and he regards these two, and the suprarenal capsules, "nerve-glands" of the sympathetic.

The Pacchionian Bodies are probably hypertrophied villi of the arachnoid membrane, developed where that membrane is exposed to much friction or stretching, consequent on the respiratory and circulatory movements of the brain.

NUTRITION, which we shall now very briefly review, is a great formative operation, to which all the processes we have hitherto described are but accessory. Its offices are development, growth, and maintenance. All parts, in performing their function, undergo destruction, and the rate of this "wear and tear" is proportional to their functional activity. Thus, every muscular contraction, even so slight as those by which I write, produces the elements of the destruction of muscle, viz., urea, water, and carbonic acid; and every mental act leads to destruction of the nervous matter of the brain, the phosphorus of which is excreted mainly as the phosphates in urine. *Mr. Paget* states four conditions are requisite for healthy nutrition: 1, a right state of the blood; 2, a regular supply of it; 3, a certain influence of the nervous system; and, 4, a normal state of the part to be maintained. 1. The blood contains, either in a crude or prepared state, all the matters which each tissue attracts and appropriates; and as *Treviranus* well expressed it, "each single part of the body, in respect of its nutrition, stands to the whole body in the relation of a secreted substance." This law explains the presence of many parts otherwise apparently useless; but they withdraw from the blood matters whose retention would be injurious. One organ or tissue is complemental to the others. Either albumen or fibrin, or both, are the main nutritive matters. The white cells, too, as has been stated, seem concerned in the process; but the red cells, from not agreeing in size with those of any tissue, are not directly engaged in tissue-forming, but rather carry oxygen for their activity and subsequent destruction. 2. Every surgeon must have seen the effect of a diminished supply of blood in producing want of nutrition and gangrene in a limb; and *Hunter's* experiments of transplanting cock's spurs to their combs, where they increased enormously, show the effect of an augmented supply of blood. 3. As nutrition goes on in plants, in animals before their nervous system is developed, and in acephalous fœtuses, its influence over the process has been denied. It is, however, proved, for instance, by the sloughing of the cornea which follows division of the trifacial nerve, especially beyond the Casserian ganglion, an effect which seems to show that this regulating power rather belongs to the sympathetic. In many invertebrates, too, the presence and size of ganglia, and certain organs, correspond—as likewise their changes during metamorphosis. 4. A healthy condition of the part is evidently necessary to produce new additions of similar matter; and even in disease, as shall be afterwards noticed, the special condition of the part keeps up a modified nutrition, producing similar structures. It has been objected that complete molecular changes cannot occur in such organs as the brain, which stores up impressions made upon it many years before; but *Prof.*

Paget, in his classical lectures on Surgical Pathology, eloquently says: "The answer is, because of the exactness of assimilation accomplished in the formative process: the effect once produced by an impression upon the brain, whether in perception or in intellectual act, is fixed and there retained; because the part, be it what it may, which has been thereby changed, is exactly represented in the part which, in the course of nutrition, succeeds to it. Thus, in the recollection of sensuous things, the mind refers to a brain in which are retained the effects, or rather the likenesses of changes that past impressions and intellectual acts had made. As, in some way passing far our knowledge, the mind perceived and took cognizance of the changes made by the first impression of an object acting through the sense-organs on the brain; so, afterwards, it perceives and recognizes the likeness of that change in the parts inserted in the process of nutrition. Yet here also the tendency to revert to the former condition, or to change with advancing years, may interfere. The impress may be gradually lost or superseded, and the mind, in its own immortal nature unchanged and immutable by anything of earth, no longer finds in the brain the traces of the past." Growth differs from nutrition in there occurring, besides the renewal of destroyed tissue, the addition of more material, which increases the size, weight, and function of the part. It is but a difference of degree. Growth does not always cease with the apparent maturity of the body, as the heart and arteries enlarge even to hale old age, increased propelling force being then required owing to the rigidity of tissues. The controlling influence of the nervous system and the modifying effects of disease will be hereafter considered.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Enumerate the ductless or vascular glands.
2. Describe the capsule of the spleen and its processes.

3. Sketch the position, structure, and supposed functions of the suprarenals.
4. What uses have been attributed to the thyroid body ?
5. Which of the ductless glands are most like nervous matter ?

SENIOR.

1. Describe the spleen-cells and their surrounding vessels.
2. What facts respectively support the theories that the spleen is a blood-reservoir and a cell-former ?
3. What effects on the lungs of an animal does close confinement produce, and how have they been removed ?
4. Compare the structures of the thymus and thyroid.
5. What are the requirements for healthy nutrition according to *Paget* ?

INNERVATION.

ANIMALS are most plainly distinguished from the other division of the organic world by a function which controls all other physiological processes, by conveying impressions to, or from, nervous centres along conductors we term nerves.

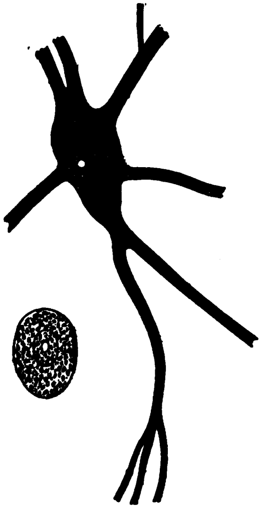
Neurine, or nervous matter, is the agent employed in this mysterious function. It is a white or grey opaque and soft substance, mechanically supported by areolar tissue or blood-vessels. The specific gravity of that of the brain is 1·039. Its composition varies at different periods, as will be seen by the following analyses of the brain :

	Infants.	Adults.	Old Men.	Idiots.
Water	82.79	72·51	73·85	70·93
Albumen	7·00	9·40	8·65	8·40
Cerebral fat	3·45	6·10	4·32	5·00
Osmazome and salts.	5·96	10·19	12·18	14·82
Phosphorus	0·80	1·80	1·00	0·85
	100·00	100·00	100·00	100·00

The fatty substances are, besides olein, margarin, and cholesterin, cerebric and oleophosphoric acids, discovered by *Fremy*, and which exist in combination with soda, like a soap. The phosphorus is chiefly united with the latter acid, and seems to be proportional to the activity of nervous function, during the exercise of which it is oxidised and excreted as phosphates in the urine.

Nervous matter is of two kinds, readily distinguished by colour, the grey and white, and still better identified as the vesicular and the tubular by the microscope.

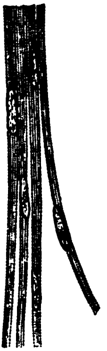
Vesicular Neurine covers the surface of the brain—hence the ill-applied term of cortical—but lies in the substance of the spinal cord and ganglia. It is softer and more vascular than white neurine, containing more water and less fat. The vesicles are large, contain a nucleus, which is also cellular, possessing a bright nucleolus, and much pigmentary granular matter, which, with that between the vesicles, gives the characteristic dark grey tint. They are ovoid or spheroid in the sympathetic ganglia, and stellate or caudate in the cerebro-spinal centres, the largest specimens occurring in the locus niger of the crus cerebri. It is probable, but can be hardly regarded as certain, that these caudate projections are continued into the nerve-tube. Such is figured by *Kölliker*, after a drawing by the *Marquis Corti*, and the continuity may be demonstrated in the ventral ganglion of the leech. *Owsjannikow* asserts that the cells in the spinal cord are



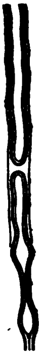
Ovoid Sympathetic Nerve-Cell.

Stellate Cerebro-Spinal Nerve-Cell.

bipolar, sending one into the motor root, the other into the sensitive.



Gelatinous nerve-tube.



Cylindrical nerve tube.

Nerve-tubes are of two kinds, gelatinous and cylindrical—here figured. The first, so named by *Henle*, occur in the sympathetic and special sense nerves. They are grey, the white matter with which the next kind is coated being absent. Oval nuclei give them a varicose outline, and they much resemble unstriped muscular fibres; their diameter averages $\frac{1}{5000}$.

2. Cylindrical nerve-tubes form the great mass of the white substance of the brain, spinal cord, and nerves. They are placed parallel, and in nerves are connected by areolar tissue. Their average width is $\frac{1}{3000}$. With a high power and transmitted light, three cylinders can be seen to constitute the tube:—1. A homogeneous membrane, analogous to myolemma, and to it the term neurilemma (which is now applied to the connecting areolar tissue of a nerve) appears suitable. 2. The white substance of *Schwann*, an opaque tube, defined by an inner and outer dark boundary line. 3. The rest of the tube is termed the axis cylinder of *Purkinje* and *Rosenthal*, and forms from one-third to one-half its entire diameter. It may be that during life, and at a temperature of 98°, these matters are combined, and only separate by a kind of coagulation after death. The white substance consists mainly of fat, and seems to have insulating properties, the axis cylinder being probably the true conductor. The continuance of the white matter, even to the termination of many nerves, throws some doubt on its insulating properties. It varies in thickness remarkably in nerves, those of young animals and of the organs of sense having so thin a layer of it, that mechanical injury

often ruptures it, and produces a nodulated or varicose appearance. The white substance is rendered laminated and brown by chromic acid, which does not affect the axis cylinder; carmine, on the other hand, stains the latter, not the former, and hence there is supposed to be some chemical difference between these two constituents of nerve-tubes.

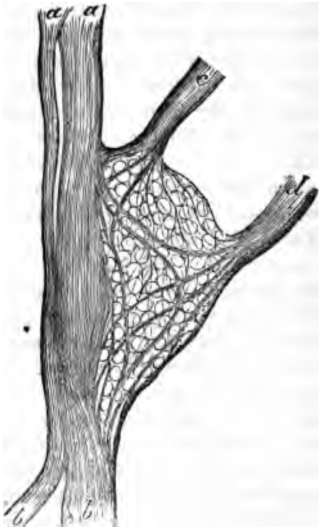
A nerve-tube runs uninterruptedly from the nervous centre to some peripheral point without any anastomosis whatever; there are thus inconceivably numerous points on the centres, each connected, throughout a special nerve-tube, with a corresponding point in a muscle or sensory surface, as the case may be. Their relation to nerve-vesicles has been alluded to, and there is also reason to believe they form loops in the nervous centres, as in cases where various portions of the cerebro-spinal axis were absent, the nerve-tubes have been observed to turn upon themselves in the cranio-spinal cavity, and run back to the same nerve-trunk. At the periphery they end in, 1, branching lashes, as in the retina, olfactory and auditory expansions, and in the electric organs of the ray; white substance is absent or very scanty, and vesicles are often added; 2, in loops, as in muscles, in skin, mucous and serous surfaces, which being plane, render this arrangement necessary, also in the papillæ of the tongue and tooth-pulp; 3, by free extremities, as in Pacinian corpuscles and tactile papillæ, which will be hereafter described.

A Nerve is a bundle of such tubes as we have described, bound together by areolar tissue, which is termed the neurilemma, and which serves to support the abundant capillaries. An artery occasionally runs through the interior of a nerve, as in the optic and sciatic.

A Ganglion is a mesh of nerve-tubes, in the interstices of which vesicles lie, as figured on the following page. We shall treat of them in describing the nervous centres.

Branches come from a nerve usually at an acute angle, and they may join those of other nerves, forming an intricate web we call a plexus.

Plexuses insure more harmonious action, and prevent loss of motion or sensation if one nerve should be destroyed. That the nerve-tubes of any one nerve emerge distinctly from the plexus, and are distributed to the tissue for which they were destined, is shown by irritating any of them which go to muscular tissue, when only those muscles under the influence of the original nerve are affected.



A Sympathetic Ganglion and its Roots. *a, b. Vertical sympathetic nerve tubes. c, d. Spinal nerve tubes which interlace, oval nerve vesicles being deposited in the meshes.*

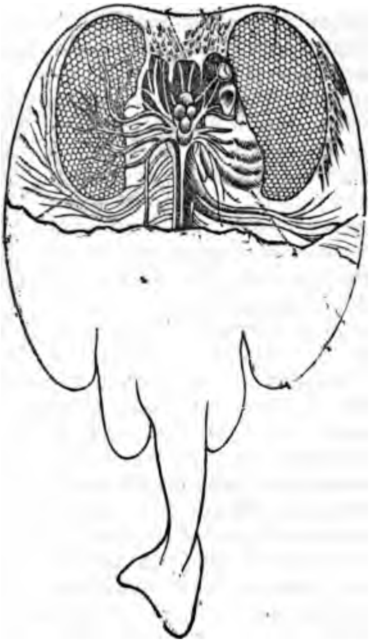
This brief account of the histology of nervous tissue will be concluded with a few remarks on its development and repair. *Schwann* found the vesicles in the early fœtus closely resembled their adult state, save in being smaller and lighter coloured. He regarded the tube as merely a number of cells which had coalesced in the same way as muscle is supposed to be developed. It is at first a pale, nucleated band, which can be split into shreds, and it then resembles the permanent state of gelatinous nerve-tube. The white substance is next gradually deposited on the inner surface of the tubular membrane, in the same way as the sarcous element is laid down in the muscle-cell, and thus the cylindrical nerve-tube is perfected. Unlike many other tissues, nerves, when divided, become repaired by new tubes being formed between the cut ends. *Dr. Haighton*, by the following experiment, discovered that their function was restored. He divided both pneumogastrics high in the neck of an animal, and death at once ensued. He then divided one, and the other in 8 weeks after; this animal survived—indicating that the first nerve had united by conducting medium. When the supra-orbital nerve is merely divided for the cure of brow-ache, the nerve often re-unites and the disease is reproduced. The frequent occurrence of amaurosis after it, has now made this operation unadvisable. The conducting power of a divided median nerve is said to have been rapidly restored by suture in some experiments before the French Academy. *Schiff* states that a divided motor nerve will not unite with a sensitive one, but will do so with any other motor nerve. It has been proved in the dog that portions of nerve wholly excised will unite with the subcutaneous areolar tissue, losing, however, everything but their neurilemma.

Nervous Force is that agent which vesicular neurine generates—hence called dynamic, and which nerves conduct—hence they are termed internuncient. We only know it by its effect on the parts where nerves are distributed, for it produces no visible change on nervous tissue. Impressions are either carried to the nervous centres along nerves, which are therefore termed afferent or centripetal, or from the centre to periphery along nerves which are termed efferent or centrifugal. These kinds of nerves correspond respectively to sensitive and motor, and no characteristic appearances distinguish them, save that the tubes of the former are much smaller than those of the latter. Impressions are sometimes carried from centre to periphery along sensitive nerves, as in cerebral disease, producing painful sensations in the extremities, and in irritation of a nerve, producing pain where its filaments are distributed, as so often seen in hip-disease, in which the sensation is carried by the obturator and long saphenous nerves to the knee. The conduction of an impression from a part which has been altered in position, is shown in an interesting way after rhinoplastic operations, where an impression on the new nose is referred to the forehead, from which the skin had been abstracted.

Special-sense nerves, we have seen, differ histologically from those of common sensibility; and they differ still more remarkably in function, for irritation of them does not produce pain, but gives rise to subjective phenomena peculiar to each—for example, muscæ volitantes, perverted smell, morbid tastes, tinnitus aurium, &c., symptoms which every physician knows are often due to centric disease. Those who suppose that nerves generate force when irritated by mechanical or other stimuli call this inherent power "vis nervosa" or neurility. Division of a nerve, a tight ligature or pressure such as tumors often produce, will interrupt the conduction of a sensation centrad, or of a motor influence peripherad. These facts can be well illustrated by tying two ligatures on a nerve which contains both sensitive and motor fibres; irritation between the ligatures will produce no effect—but if the lower one be removed, motions will occur; or if the upper one, pain will be felt. The rate of transmission of nervous force is about 86 feet per second in the frog, and 200 in man; whereas electricity travels 462,000,000 feet in the same time.

Theories of Nervous Force have been numerous. For many years *Descartes'* supposition of a nervous fluid was accepted, till *Hartley* maintained that the influence was transmitted by vibrations. The resemblance between nervous force and electricity has been often dwelt on since the discovery of *Galvani*, and especially by *Wilson Philip*. Both are transmitted with wonderful rapidity along conductors, but the velocity of electricity is far greater—both require two dissimilar substances to excite human body has been much exaggerated; it has been even considered capable of accounting for that physical impossibility—"spontaneous combustion."

The Electric Fishes are the torpedo, gymnotus, trichiurus, malapterurus, and tetraodon. The torpedo grows to 4½ feet in length, and has weighed 73 ℔. The French peasants use all parts, except the electric organs, as food. Symmetrically beside the head, as shown in the annexed figure are two great masses of nervous matter arranged in columns, and connected with the tri-



Electrical Organs of the Torpedo, supplied by the pneumogastric nerves.

facial and vagus nerves. These are the electric organs, and the resemblance between them and many voltaic arrangements is striking. *Dr. M'Donnell*, of the Carmichael School, has discovered organs homologous to them in the common skate. The gymnotus may attain a length of 20 feet. Its organs are arranged in laminæ, run the whole length, and form the chief bulk of the animal. The electricity developed by these creatures is identical with that generated by the galvanic battery, the frictional machine, and other means, as the following facts will show: 1. Shocks have been felt by 27 persons who joined their hands, the first and last touching the fish. 2. The galvanometer needle has been deflected to 33°. 3. A magnet has been made. 4. Chemical decomposition or electrolysis of iodide of potassium and other substances has been effected. 5. Heat has been evolved, even sufficient to fuse gold leaves. 6. The spark has been obtained. *Spallanzani* felt the spark from the fœtus just removed from a pregnant torpedo. All electric power ceases the instant the animal dies, or when the connexion between the organs and the nervous system is severed, but by irritating the end of the nerve connected with the organ, discharges are produced. It seems controlled by the will of the animal, and after repeated discharges, it loses the power, and is then easily captured. While thus convinced of the identity of animal with other kinds of electricity, *Schönbein* remarks: "So long as we are without an exact idea of what electricity is, the different modes of its development will of course be incomprehensible to us, even though anatomists and physiologists should have very carefully studied the structure of the fish;" and we must conclude that the forces are not identical, though correlated, as the physical forces have been shown to be by *Groves*. Growing plants give rise to electric actions, which shows that the presence of a nervous system is not essential.

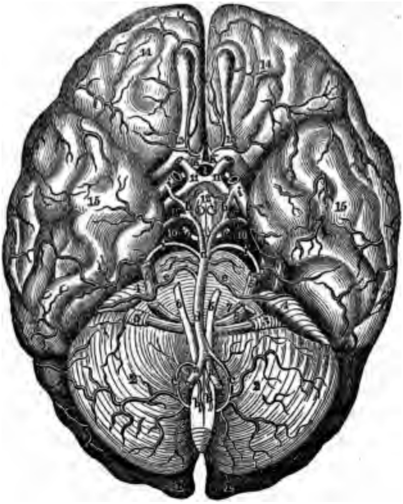
Luminosity, which some invertebrates, and occasionally even the human body evolves, has been said to be due to electricity. The phosphorescence observed in the tracks of vessels is due to minute infusoria and medusæ, the nervous system of which, according to *Ehrenberg*, produces the phenomenon; but in some luminous animals, noctiluca, for instance, no nervous system can be demonstrated. Among insects, the fire-fly and glow-worm emit light, particularly about the reproductive organs. It continues very slightly after death, but may be increased, as *Darwin* found, by mechanical irritation. It is due to oxidation, for if the creatures are placed in any irrespirable gas, or in vacuo, it ceases. Phosphorus is probably the material which is slowly oxidised, for we can produce great luminosity by injecting an oily solution of that substance into the veins of a dog. The same appearance has been remarked in the urine of persons to whom that drug was administered; and in cases of poisoning by phosphorus, the luminosity of the viscera is the main test for its diagnosis. *Sir H. Marsh*—to whom we owe almost all our information on the evolution of light from the human body—records that the individuals in whom he noticed it were suffering from phthisis, and death was approaching—a degree of decomposition, however, preceding it. The breath had a peculiar putrid odour. In one case the light appeared 10 days before death. It was "silvery, like the reflection of moonlight on water, or like that of the aurora borealis."

In one case, *Dr. Stokes* found so much light emitted from a cancerous ulcer, that the hands of a watch-dial could be distinguished in the dark. Bodies in the dissecting room, and many decomposing animal substances, often show a phosphorescence, which can be communicated to any object coming in contact with them.

We shall now proceed to examine in detail the divisions of the cerebro-spinal centre:

Three Membranes clothe the brain and spinal cord: 1. The dura mater, a white fibrous covering which supplies the cranial bones with blood in early life, but is less closely attached about the spinal cord, gives off processes which divide and support the parts of the brain, sheathes every nerve as it emerges, and lastly forms that freely communicating system of veins we call the sinuses. 2. The arachnoid is a continuous serous sheet lining the dura mater—save where the pituitary body intervenes—the outside of the brain and spinal cord, and in fœtal life passes through the canal of *Bichat* to line the ventricles. This communication is subsequently obliterated in the same way as the tunica vaginalis is shut off from the peritoneum. *Sharpey* believes the arachnoid is inflected through the fissures, and lines the subarachnoid spaces. The membrane pours out a halitus which facilitates the motions of the brain. *Rainey* states that it is most abundantly supplied by sympathetic filaments—but if so, it must widely differ from other serous sacs. 3. The pia mater, an areolar-vascular web which dips into all the sulci and conducts blood-vessels into the substances of the brain. On the spinal cord it is far less vascular, and acts more as a tight fibrous sheath which ends below in a thread, the filum terminale of *Macartney* tying it down to sacrum. Together with the arachnoid, the spinal pia mater forms two bands between the anterior and posterior roots of the nerves, with a straight edge attached to the side of the cord, and a serrated edge, consisting of about 22 teeth, attached to the intervertebral foramina. They are termed ligamenta dentata, and are represented at page 272. They steady the cord.

The Subarachnoid Fluid, first noticed by *Cotunnius*, far more copious than that in the arachnoid sac, as it ually exceeds two ounces. It is alkaline and slightly buminous, containing no materials out of which the rvous matter could be laid down, as once supposed. is abundant according as the amount of blood or size ervous centre is diminished, thus keeping up a compensatory pressure. It affords an equal fluid-pressure to the brain and delicate nerve-filaments, especially at the base of the brain. If removed by puncture of the arachnoid, it is rapidly re-secreted by the pia mater; and thus pints of it are occasionally poured through the ear in fractures of the base of the skull—a symptom, as *Colles* remarked, almost surely fatal.



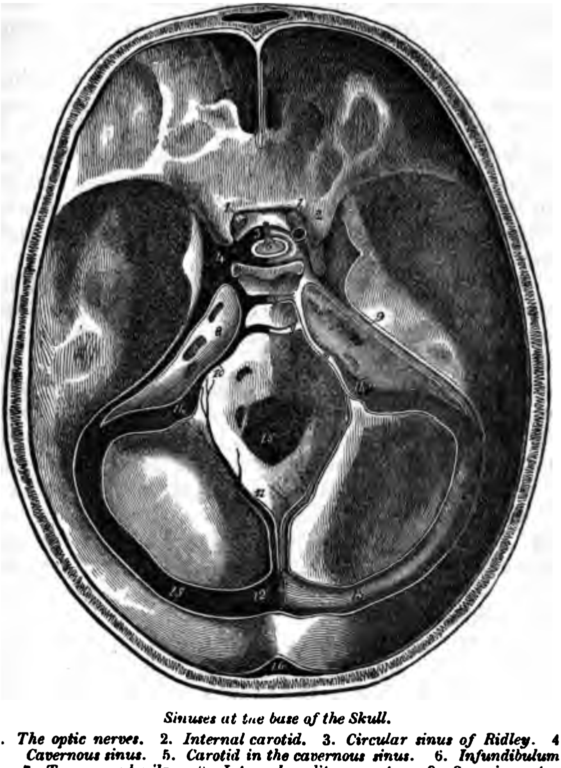
The Base of the Brain.

1. *Posterior cerebral lobes.* 2. *Cerebellum.* 3. *Pneumogastric lobules.* 4. *Anterior cerebellar lobe.* 5. *Trifacial nerves.* 6. *Abducens nerves.* 7. *Facial nerves.* 8. *Auditory nerves.* 9. *Oculo-motor.* 10. *Crura cerebri.* 11. *Optic commissures and nerves.* 12. *Pisiform bodies.* 13. *Olfactory roots.* 14. *Anterior lobes.* 15. *Middle lobes.*

The Circulation of the cerebro-spinal axis is peculiar: 1. For the quantity of blood (which even *Hippocrates* remarked, and it suggested to him that the brain was a secreting gland). *Haller* estimated it at one-fifth of the entire. The generation of nerve-force requires a free circulation of blood, and thus it is that the benumbing influence of cold dulls cerebro-spinal action. 2. The blood is made to ascend against gravity through very tortuous arteries, which then break up into the circle of Willis at the base of the brain. Some special arrangements in lower animals are described at page 142. 3. The vessels cannot dilate, as they pass through bony canals or fibrous sheaths. 4. The arteries do not penetrate the nervous substance, but ramify freely on its surface. The cerebral arteries are figured on the previous page. 5. The capillaries and smaller arteries have much more muscular coats than those of other situations, and thus the amount of blood can be easily arranged.

Kellie first started the plausible notion that as atmospheric pressure did not bear upon the cerebral circulation, it could never vary. He bled sheep to death, and hung others with the head downwards, and stated that the amount of blood in the cranium was equal; whereas other parts were blanched in the one instance, or gorged in the other. When, however, he trephined the skull, the pressure of the air made the condition of the brain like other parts, and it varied according to the mode of death. *Dr. Burrows* disproved both these results; and the free communication between the veins of the scalp—those in the diploe, which *Breschet* described, and the sinuses—should render the cranial vessels subject to the same changes as those of other parts.

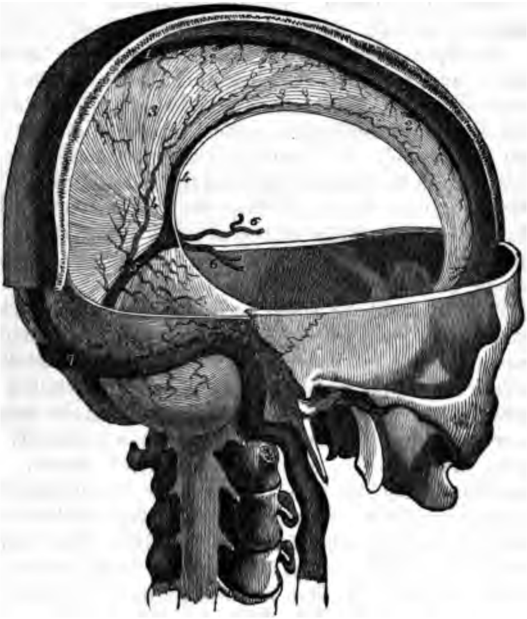
The subarachnoid fluid is also of the highest value in preserving an equable pressure on the brain, as it is vicarious in amount to the blood with the skull. There is good reason, as explained at page 243, to regard the thyroid as an organ for regulating the supply of blood to the brain. Coma, convulsions, or delirium, result from want of pressure on the cerebral mass, as well as from undue pressure upon it. This is shown in *Sir A. Cooper's* experiments of ligaturing the carotids; by the effects of hæmorrhage; when pericarditis suddenly obstructs the heart's action; and in the hydrocephaloid disease of children, which *Gooch* and *Marshall Hall* so graphically described and distinguished from hydrocephalus, more especially as regards treatment. As the cerebral circu-



Sinuses at the base of the Skull.

1. *The optic nerves.* 2. *Internal carotid.* 3. *Circular sinus of Ridley.* 4. *Cavernous sinus.* 5. *Carotid in the cavernous sinus.* 6. *Infundibulum.* 7. *Transverse basilar.* 8. *Internal auditory meatus.* 9. *Superior petrosal sinus.* 10. *Inferior petrosal sinus.* 11. *Occipital sinus.* 12. *Torcular Herophili* 13. *Lateral sinus.* 14. *Jugular foramen.* 15. *Foramen magnum.* 16. *Superior longitudinal sinus.*

lation does not materially differ from that of other places, the effect of bleeding will be to diminish its quantity of blood, and, moreover, by weakening the heart's force it will decrease the pressure upon the brain, and powerfully



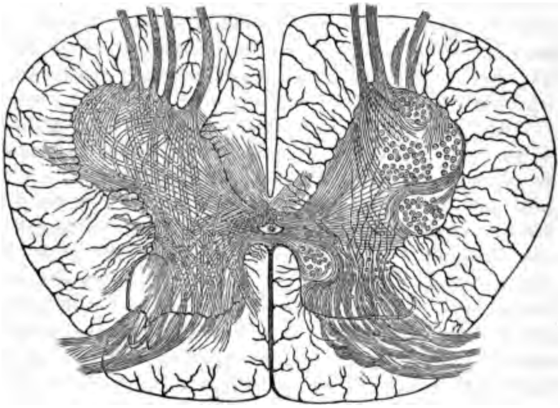
Sinuses of Skull.

1. *Superior longitudinal.* 2. *Veins of dura mater.* 3. *Falx cerebri.* 4. *Inferior longitudinal sinus.* 5. *Straight sinus.* 6. *Venæ magna Galeni.* 7. *Torcular Herophili.* 8. *Lateral sinus.* 9. *Jugular vein.*

interfere with its action. The veins which return the blood of the cerebro-spinal axis are termed sinuses, and are represented in the accompanying transverse and vertical sections. They are destitute of valves, and have no elastic coat, as it might influence an injurious backward pressure, which there would be no valves to resist.—Their number and free communication are remarkable. For an admirable description of those of the spinal column, I must refer to the article "Venous System," in "Todd's Cyclopedia," by *Dr. M'Dowel*, Professor of Anatomy and Physiology in the University of Dublin.

The Spinal Cord is the first portion of the cerebro-spinal axis we shall examine, as it is the primary element in lower animals, and the higher nervous action will be more readily comprehended when its functions are understood. In form it is a tapering mass, differing from a cylinder in being flattened on its anterior and posterior surfaces. It extends from the first vertebra—where the decussating fibres of the pyramid mark it from the medulla oblongata—to the second lumbar vertebra in adults, or to the sacrum in the fœtus.

By this ascent the sacral nerves are dragged within the spinal canal, and form the cauda equina. The brachio-rachidian and lumbo-rachidian bulbs are two swellings where the nerves to the upper and lower extremities are given off, and their respective size in various animals corresponds to the development of these members. In man, the lumbar swelling has most grey matter. The medulla oblongata, being very similar in appearance, is often termed the superior rachidian bulb, but we shall see its functions are of a higher order. The cord, on an average, weighs about 1½ oz., being much less in proportion to the brain than in other animals. A transverse section is figured on following page, after *Lockhart Clarke*, who steeps it in a solution of chromic acid, to render it transparent. It shows the division of the cord into two symmetrical halves by anterior and posterior fissures. The former is wide, dips in for one-third the antero-posterior diameter, and a white commissure unites the opposite halves, as the corpus callosum does the cerebral hemispheres. The posterior fissure is very narrow and indistinct, divides one-half the cord, and is closed by a grey band uniting the vesicular masses in a way compared to the intercrural lamina between the loci nigri of the crura cerebri. The section shows two grey masses of a semilunar shape, with the concavity outwards, and the convexities joined by the grey commissure. Each mass terminates anteriorly in a rounded end, from which some fibres of the anterior root of the spinal nerves arise, and posteriorly it comes quite to the surface, when it seems to form directly the posterior roots. About midway between the grey commissure and the posterior roots, there is found "the gelatinous substance" described by *Rolando*, which consists of much vesicular neurine and longitudinal fibres. The relative amount of grey matter increases from above downwards. The groove where the posterior roots emerge marks the cord into an antero-lateral column, extending from thence to the anterior fissure, and a posterior column reaching to the posterior fissure. The anterior and posterior roots of the nerves are con-



Transverse Section of Cord. at the lumbar enlargement, showing on the right the grey mass, and on the left, the course of the root fibres. The ventricle is seen in the middle of the grey commissure.

nected with antero-lateral columns, which are also joined by a commissure, according to most anatomists, save *Clarke*, who states the commissure is composed entirely of grey matter; whereas the posterior columns are quite severed—except in the dorsal region, where the posterior fissure can be scarcely distinguished. In the centre of the grey commissure is seen a canal, lined by cylindrical ciliated epithelium, and extending even to the filum terminale. It is continuous with the fourth ventricle, about $\frac{1}{100}$ in diameter, and in birds dilates at the lumbar swelling into the sinus rhomboidalis.

The fibres of the spinal cord are thus arranged by *Todd* and *Bowman*:—1. Spinal oblique or transverse. 2. Encephalic, longitudinal. 3. Longitudinally commissural. 3. Transversely commissural. The view still held by some anatomists, that all the fibres proceed from the brain, is disproved by the fact that the cord does not uniformly taper from above downwards, which should be the case if, like a great nerve, it gave off these fibres as it passed along. The size of the cord really corresponds to the number of nerve-tubes given off at any point, as proved by the following calculations of *Volkmann*, who gives the weight of 4 segments, each 7 centimetres long, from the cord of a horse, and the respective extent of the grey matter in square lines:

	Grains.	Area of Grey. Matter.	Area of White Matter.
From below 2nd nerve	219	13	109
,, 8th ,,	293	28	142
,, 19th ,,	163	11	89
,, 30th ,,	281	25	121

It was *Grainger* who first stated that some of the fibres had their origin in the cord itself.

The Functions of the Cord will be best understood by arranging them into—1, those which it possesses as an independent centre, and 2, those it performs for the brain. Division of the cord deprives all parts below of the endowments of sensation or voluntary motion. The section has been made on living animals; and disease or injury too often perform the same experiment on man, whose body is then "like a living head and a dead trunk—dead to its own sensations and to all voluntary control over its movements" (*Todd* and *Bowman*). The amphioxus or lancelot fish, however, seems to prove that sensation and voluntary motion may exist in animals from whom the brain is absent, for this creature's cord tapers as finely at one extremity as at the other; and the cephalic ganglion which exists seems merely to minister to special senses. As we stated before of an ordinary nerve, if the cord be divided, irritation of the upper segment will produce pain and movement of all muscles which derive their nerves from above the section; irritation of the lower will excite only movements. Division of one half will produce these effects on the corresponding side only. A stimulus applied to the skin or other sensitive parts will also excite involuntary movements. *Hunter* relates that irritation was applied to the lower extremities of a man whose spinal cord had been severed by injury; they jerked vigorously. Being asked if he felt the irritation, he replied: "No, sir; but you see my legs do," and in that answer is embodied most of the views now entertained on the independent endowments of the spinal cord. That such movements are truly spinal, having no dependence on the brain, is still further shown by their occurring in brainless fœtuses and pithed or even decapitated animals; but if the cord be removed from the latter, all capability of motion ceases.

This excito-motory function of the cord, alluded to by *Whytt* and *Prochaska*, was so named and admirably investigated by *Marshall Hall*, who considered the "true spinal cord" as extending as far as the crura cerebri, and consisting of excito-motor fibres, grey matter, and reflecto-motor fibres, quite distinct from ordinary sensitive and motor fibres, and as being the seat of all physical nervous action. Disease most strikingly illustrates this reflex function, the discovery of which has thrown a flood of light on the pathology of innervation. Many examples will be hereafter adduced, but in this place two instances will make the principles more easily understood. In children, a morbid condition of the gastric mucous membrane transmits an irritation along the excito-motor fibres of the pneumogastric nerve to the medulla oblongata, whence it is sent along the reflecto-motor fibres which branch into the recurrent nerve to the laryngeal muscles, producing that disease which *Sir H. Marsh* so well described as "spasm of the glottis." In a recent case which I saw in consultation with a former pupil, the irritant was malarious air, and the reflex disease disappeared a few days after the child's arrival in this country. A wound in the sole of the foot will so excite the polarity of the cord as to produce tetanic spasm of nearly all the muscles—those about orifices being most affected, which is usually the cause of death, and which supports *M. Hall's* view—that the excito-motory system chiefly presided over the muscles of ingestion and egestion. Strychnine is a special excitant of the reflex function, and does not act directly on the cord, for if the posterior nerves be divided it will produce no tetanoid spasms, although the animal will die. Cold, as when applied along the spine in tetanus, conium, belladonna, and tobacco, are the most powerful means we have for reducing the polarity of the cord. The physiologically antidotal power to strychnia of the latter substance, was discovered by *Prof. Haughton* of Trinity College, Dublin, and has already saved human life. Wourara appears to be a destroyer of all nervous force. The nearer to periphery the stimula to reflex action is applied, the more powerful the result—a principle which suggests that the endermic application of strychnia is preferable to its internal administration; and I have tested practically the value of the suggestion.

Cantharides also stimulates the reflex function; when administered to a patient whose spinal cord had been divided by a tumour, it restored the retentive power of the neck of the bladder, which had been lost. It has been remarked that the cord of the frog has greater purposive power than that of man, as when all connexion with the brain, where all instinctive and co-ordinating faculty is supposed to reside, is cut off, the animal will leap and try to escape any irritation applied to the feet; while the movements in man are purposeless although powerful. Decapitated frogs have been seen to swim vigorously.

Besides the examples given of reflex action occurring without sensation, the often-quoted one of the sleeping child grasping the finger placed within its hand, may be alluded to, and the well-known fact that soldiers during a fatiguing march will walk, though quite asleep, when the sensorium is inactive. 2. As regards the conducting office of the cord, the functions of the antero-lateral and posterior columns respectively, are much less positively known than those of the roots of the nerves, which are both connected with the former. *Sir C. Bell* announced, shortly after his brilliant discovery regarding the roots, that the antero-lateral column was exclusively motor, the posterior, sensitive; but *Mr. Shaw*, his son-in-law, who edited his works, states that he afterwards saw reason to doubt the latter part of the hypothesis. It is shown to be untrue by the fact that

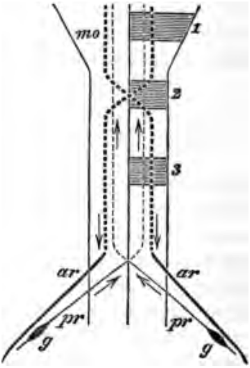


Diagram of course of Nerve Fibres in Cord.

ar. Anterior root. pr. Posterior root. g. Ganglion. mo. Medulla oblongata. 1, 2, and 3 represent sections through the medulla oblongata high up, low down, and in the cord.

the posterior column is traced into the cerebellum, which is certainly connected more with motion than sensation; and that if it be divided, all parts behind, instead of being rendered anæsthetic, become hyperæsthetic, or many times increased in sensibility—an effect due to the increased flow of blood which ensues from section of the vaso-motor nerves. *Brown-Séquard,* from whose work the foregoing diagram is copied, has shown that the sensitive fibres of the posterior root (*pr.*) cross to the opposite side of the grey matter of the cord, and so run up to the brain. The fibres of the anterior roots (*ar.*), on the contrary, do not decussate till they arrive at the pyramids. The arrows in the diagram indicate the centripetal direction of sensation, and the centrifugal direction of the motor force. These facts he has demonstrated by 3 sections : 1. Complete section of one half of the cord in the dorsal region. The effects on the limbs behind the section may be thus tabulated :

On injured side.	On uninjured side.
Motion lost.	Motion remains.
Sensibility remains.	Sensibility lost.

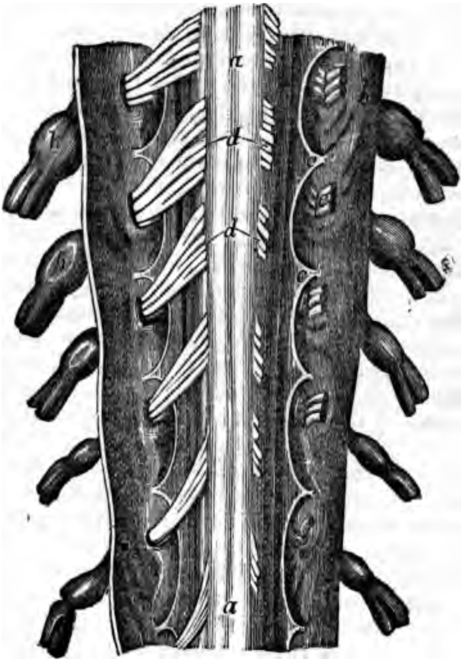
2. The preceding section having been made, the opposite half is severed completely in the cervical region, and the sensibility of the limb, which was retained after the first section, is now lost. 3. The lumbar part of the cord is divided from its anterior to posterior fissure, and all sensitive fibres which come from the hind limbs and cross each other in the commissure being divided, all sensibility of these members is destroyed, but motion remains. The decussation of the sensitive fibres along the cord, and of motor ones only at the medulla oblongata, would account for the anomalous case recorded in the French translation of *Sir C. Bell's* work, where an injury to the spine produced paralysis of one limb and anæsthesia of the opposite. Half the cord was probably severed. *Brown-Séquard* concludes, from experimental

and pathological proofs, that the grey matter and not the posterior columns, as believed by *Longet*, are the conductors upwards of sensibility.

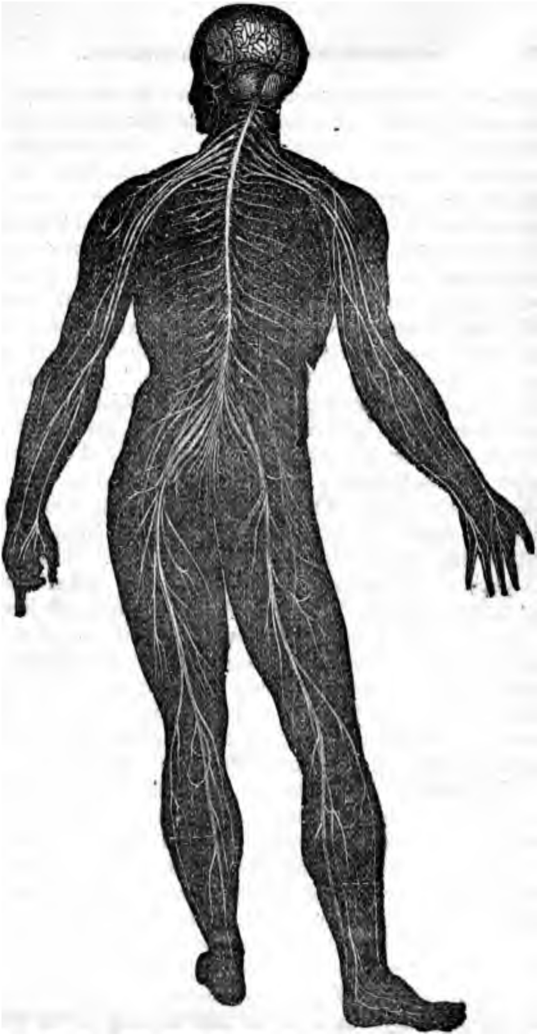
There is no evidence to support *Valentin's* theory that the anterior column presides over flexion, posterior over extension, nor that which assigns the control over these movements to the upper and lower halves of the cord respectively. There is much pathological and other evidence to support the views of *Todd* and *Bowman*, who regard the posterior column as "in part commissural between the various segments of the cord, and in part subservient to the function of the cerebellum in regulating and co-ordinating the movements necessary for perfect locomotion," to which, I may add, that it may be the conductor of muscular sense to the cerebellum, where we shall show that that power resides.

The Roots of the Spinal Nerves are two—an anterior—small, white, and motor; and a posterior—larger, grey, and sensitive, forming also a ganglion, after which it is joined by the anterior. A filament from the sympathetic is sent to all these ganglia. The nerve-tubes of both roots are continuous in loops in the grey matter of the cord. The great physiological facts that the anterior roots are motor, the posterior sensitive, and the branches compound, were the discoveries of *Sir C. Bell.* In a rabbit (but from the greater period excitability lasts, its few nerves, and the wide space in the canal by the side of the cord, the frog is fitter for experiment) he divided the anterior roots on one side, the posterior on the other; irritation on the side where posterior roots were divided produced no effect, as the impression could not be carried up; but when applied to the other side, there were wincing, cries, and other evidences of pain, as the impression was conducted to the cord, and produced on the other side vigorous movements. This simple but beautiful experiment, besides demonstrating the respective functions of the roots, proves that sensitive impressions are transmissable from one side to the other of the cord.

Irritation of the detached portion of the anterior root will produce motion—but of the posterior root, no effect. The function of a nerve may be also gathered from its distribution—if to a muscle, it must be motor; if to skin, &c., sensitive. The fact that there is muscular



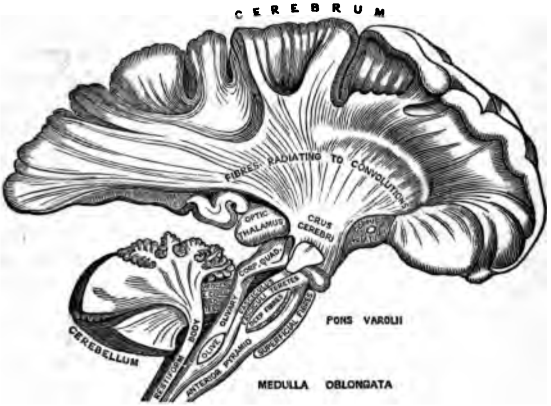
The Spinal Cord, its Membranes and Nerve-Roots.
a. The cord. b. Dura mater. c. Denticulate ligament. d. Posterior or sensitive roots cut on the right side. e. Entire on the left of the anterior or motor roots. h. The ganglia on the posterior roots, beyond which the anterior roots unite to them, to divide again into anterior and posterior branches.



The Cerebro-spinal System—Brain, Cord, and Nerves.

tissue in the skin does not disprove the statement, as the spinal nerves are compound, and filaments from the anterior roots may supply the tissue. The sympathetic may also supply the contractile tissue of the skin, but as the phenomenon of cutis anserina is perceived over the extremities where that nervous system is scantily, if at all, distributed, it is more probable that its source is the spinal nerves. A few filaments may be traced running from the posterior root to the anterior, and the sensibility they confer threw some doubt on the statement, that the latter was exclusively motor; but these fibres may be regarded as merely "nervi nervorum." They plainly come from the posterior root, as all sensibility is lost by its division, and irritation of the central portion of the divided anterior root will not produce pain, though irritation of the detached half will, as it is carried back by the posterior root. The two roots unite after the posterior has formed the ganglion, and then two branches, of which the anterior is the larger, separate. There are 31 pairs of spinal nerves—or, adding the spinal accessory, as *Willis* did, 32, arranged as 8 cervical, 12 dorsal, 5 lumbar, and 6 sacral, the anterior branches of which mingle together, and form the cervical, brachial, lumbar, and sacral plexuses. The only posterior branches which form a plexus are those of the first four cervical. The general arrangement of the cerebro-spinal axis and the spinal nerves will be seen in the preceding figure.

The Medulla Oblongata is an oval mass continued from the cord into the cranium; like it, it is divided into halves by a posterior fissure—at the bottom of which, however, no grey commissure exists—and an anterior, across which are found many fibres decussating to the opposite side. Each half is marked by grooves into 4 bodies, termed, from before backwards, the pyramid, olivary, restiform, and posterior pyramid. *Solly* and *Rolando* have described arciform fibres, which curve under the olivary body—as it is but half as long as the other bodies—and uniting the pyramid and restiform, pass back to the cerebellum ; and they may explain the crossed character of lesions of that organ. The pyramid consists of fibres, both from the antero-lateral column of its own side and of the opposite, which, we have stated, decussate across the anterior fissure. These fibres can be traced upwards through the deeper fibres of pons, lower layer of crus cerebri, and thus into those ganglionic masses, the optic thalamus, corpus striatum, and finally into the hemisphere, as is represented in this diagram of the physiological method of dissecting the cerebro-spinal axis from below upwards. Their course very clearly accounts for cross-paralysis in cerebral lesions, the limbs of the opposite half of the body being paralyzed. The olivary body exists only in man and quadrumana, but in some other animals the great size of the pyramid may conceal it. It contains a grey ganglionic mass, the corpus dentatum, which seems connected with



The Fibres of the Antero-Lateral Tract traced through the pyramid and olivary body, deep part of pons, crura cerebri, optic thalamus, and corpus striatum into the hemispheres, and those of the posterior tract through the restiform body into the lateral lobe of the cerebellum, after Gray.

the functions of the tongue, as both glosso-pharyngeal and lingual nerves have some filaments arising from it. The fibres of the olivary body extend from the antero-lateral column, through the pons and crus, into the optic thalamus and quadrigeminal bodies.

The restiform body, so named from its twisted appearance is mainly continued from the posterior column. As it ascends it diverges from its fellow, and joining the lateral lobe of the cerebellum, has been termed "processus e cerebello ad medullam oblongatam." It is said to have a small grey mass at the origin of the pneumogastric. The posterior pyramid seems merely a portion of the restiform marked off by a very superficial groove; but unlike it, *Solly* says, it passes to the opposite side of the pons. A grey mass on the back of the medulla, just below the fourth ventricle, is regarded as the auditory ganglion. Some fibres were described by *Cruveilhier* as passing antero-posteriorly, like a septum, in the middle of the medulla. There are many transverse fibres also mainly connecting the olivary bodies, which, from this fact and their abundant vesicular matter, must be regarded as the seat of all the independent functions the medulla possesses. The 8th, 9th, and facial portion of 7th, are most intimately connected with the medulla, which, through them, controls the great acts of respiration and deglutition. In animals which breathe without a diaphragm, the spinal cord, and in frogs the cerebrum also, may be sliced away without interfering with respiration; but destruction of the medulla at once kills by apnœa, unless they are etherized; and irritation of this centre produces spasm of the respiratory and pharyngeal muscles. It is therefore the seat of such reflex acts, as vomiting, coughing, &c., which we have before considered. In fœtuses where the cerebral lobes are suppressed, in the kangaroo before they are developed, and in puppies from which they have been removed, the power of sucking exists, dependent, as *Grainger* remarks, on the medulla. *Van der Kolk* regarded the olivary bodies as ganglia of speech through the lingual nerves.

The Cerebellum, or lesser brain, is about one-sixth the size of the cerebrum, and consists of 3 lobes, of which the middle is found in all vertebrates save the amphioxus; and the lateral lobes are added in birds and mammals—never, however, except in man, attaining an equal size with the most essential part. Like most other ganglionic masses, its surface is arranged in convolutions, which are narrower, straighter, and deeper than those of the cerebrum. The sulci are either primary, dividing the lobes into about 5 lobules, or secondary, which cut these again into lamellæ. The middle lobe is curved forwards, and ends above and below in a vermiform process. The central stem of each lateral lobe is white and branched, like a tree, the "arbor vitæ," in the inner third of which there is a grey mass with an irregular edge, the "corpus dentatum," which is very similar to that found in the olivary body. The cerebellum is connected to the mesocephale by the "processus e cerebello ad testes," whose fibres extend as far as the optic thalami, and the "processus e cerebello ad pontem," or crus, whose fibres form the superficial part of the pons, which is therefore a transverse commissure of the cerebellum: the "processus e cerebello ad medullam oblongatam," or restiform body, joins it to the medulla. The grey matter or cortical substance has large vesicles with the caudæ projecting towards the surface, which fact is evidence against the continuity of these processes and nerve-tubes. Between the cerebellum, mesocephale, and medulla lies the 4th ventricle, on the floor of which is seen a longitudinal groove, the "calamus scriptorius," continued up from the posterior fissure of the cord. The auditory nerve takes root at its posterior or plume-like extremity; and *Dr. Alcock*, late Professor of Physiology, Queen's College, Cork, traced the trifacial nerve to the anterior extremity. It was here that *Flourens* thought he discovered a "nœud vital," or vital point, as injury of it often causes instantaneous death; but it has been removed in frogs without fatal effects following for some days.

The experiments of *Magendie* and *Flourens* have clearly shown that the function of the cerebellum has more connexion with motion than any other nervous endowment. In pigeons, *Flourens* sliced it away, and no pain was produced; but the animal performed rapid, irregular, and unharmonious movements, which could not be co-ordinated into their usual acts of standing, walking, or flying. Common and special sensation, and probably volition, were retained. The condition has been aptly compared to that of a drunken man. Section on one side only gave rise to rapid gyrations of the body from that side, even to the number of 60 per minute, and lasting for some days; but *Brown-Séquard* has shown that a much less important injury, as division of the auditory nerve, will produce this effect. *Serres* reports that rotations occurred in a man in whose crus cerebelli an apoplectic clot was found; and they have been observed in a case in which, after death, an exostosis was discovered pressing on the same point. Unsteady gait has been found a pretty constant symptom of disease of of the cerebellum. *Flourens* then regards the cerebellum as the co-ordinator of movements.

Foville believes it is rather the organ of muscular sense, which its close connexion with the posterior column of the cord and the quadrigeminal bodies renders very probable; but it is not inconsistent to suppose that it fulfils both these offices.

Gall started the notion that the cerebellum was the seat of the amative and propagative instincts. It was merely one of those unfounded guesses which have been often substituted for rational opinions founded on laborious research. It is contradicted by the numerous connexions of the cerebellum, whereas it would be alone connected with the generative organs if such were its functions, and its vast proponderance in man over reptiles and fishes, which possess the reproductive impulse in a much higher degree. Again, in the ray and eel, which copulate, it is much smaller proportionally than in the cod, which does not. Phrenologists have espoused this idea, and they account for the large size of man's cerebellum by the constancy of venereal desire, which is periodic in other animals. Disease, injury, or removal of the organ has not diminished the activity of the generative function ; and, on the other hand, the gelding's cerebellum has been found heavier than the mare's or stallion's, which may be due to their not being employed in ordinary work, which would develop the co-ordinating power. *Curling* has lately dissected an idiot, whose testes were rudimentary—one weighing 20 grains, the other 37 ; yet the cerebellum was the average weight. The correlation of the cerebellum to other nervous centres is thus expressed by *Flourens:* " The cerebrum feels and wills ; the medulla oblongata and spinal cord execute ; the cerebellum co-ordinates." The movements of decapitated frogs must force us to regard the cord as having co-ordinating power.

The Mesocephale includes the pons and quadrigeminal bodies. As the pineal gland seems more connected with ductless glands than nervous structure, we have elsewhere described it. The pons consists superficially of bridge-like fibres passing from one lateral lobe of the cerebellum, through the crura, to the other; and the commissural fibres are absent in animals which possess a middle cerebellar lobe only. Its deeper portion is formed by the fibres of the pyramids and olivary bodies passing up to the crura cerebri. Some grey matter which is found in the pons suggests that it may have ganglionic function.

The Quadrigeminal Bodies consist of two anterior or nates, two posterior or testes, the former being larger in man, the latter in all other animals. In all vertebrates below mammals but two exist, and are hollow masses, termed "optic lobes." They bear proportion in size to that of the optic nerve, but exist in the mole although the eyes are suppressed. In some pleuronectoid fishes one is much larger than the other, as the eyes are also unequal. If they be removed in animals, sight is lost in the opposite eye, which becomes amaurotic, and the pupil dilates, as the stimulus to the contraction of the pupil is not transmitted. Irritation of one body will produce contraction of both pupils—in the same way as if light be admitted to one eye, and excluded carefully from the other, the pupils will both contract.

Rotations will also occur if one of the quadrigeminal bodies be removed, as vision is wholly lost; and the same effect is produced by blindfolding one eye of a pigeon or by evacuating its humours. Amaurosis is a common symptom of ramollisement, which in some cases has been found after death localised to these bodies, which for the foregoing reasons we may consider the ganglia of vision; and the other special senses have each a similar centre. Extensive connexion between the bodies and the motor tracts is requisite, for, as *Mayo* remarks, in ordinary movements "we lean upon our eyesight as upon crutches;" and thus, when standing on a high tower, we feel insecure, as sight does not tell us we are supported.

The Optic Thalami are the next ganglia which we meet in tracing up the fibres of the cord through medulla, pons, and crura cerebri—except the grey semilunar mass termed the locus niger, which separates the fibres from the pyramid and olivary body in the latter, and from which the motor oculi nerve arises. The optic thalamus is an oval mass of vesicular matter and fibres, mainly continued from the olivary body. It has a greyish tint, like "café au lait." The geniculate bodies are little tubercles on its posterior extremity, and connected with the optic tracts. The two thalami are joined across *the 3rd* ventricle (which is merely a slit between them) by the middle and posterior commissures, and fibres freely diverge from them into the corpus striatum and hemispheres. From such connexions, then, we are led to suppose that these bodies preside over sensation, a point which neither vivisections nor pathological lesions can aid us in determining, as their effects are isolated or interpreted with great difficulty. These instruments of research, however, enable us to disprove *Foville's* assertion—that the optic thalami preside over the upper extremities, the corpora striata the lower; for *Longet* has paralysed both members equally by removing the thalami, and pathology has shown that lesions of one of those centres have as often affected the upper as the lower extremities. In cases of softening of the brain I have had to treat in St. Vincent's Hospital, I have often met with paralysis of the lower extremities in cases where, from amaurosis, there was reason to believe the thalamus the seat of the disease—an opinion in one case verified by dissection.

The Corpus Striatum has much more grey matter, which coats its surface, and is arranged in plates between the fibres traced up from the cord. The anterior commissure joins them to each other, and the tænia acts as a longitudinal commissure. From the connexion of this body with the hemispheres and the pyramids and anterior columns of the cord, their office has something to do with voluntary motion, and disease of, or removal of them, paralyzes the opposite side of the body, owing to the decussation of the pyramids.

The organs we have heretofore considered serve, in the words of *Dr. Kirkes*—" 1st. For the direction and government of all the unfelt and involuntary movements of the parts which they supply; 2nd. For the perception of sensations; and, 3rd. For the direction of such instinctive and habitual movements as do not require the exercise of judgment, deliberation, memory, or any other intellectual act."

The distinctness of the fibres in that prolongation of the cord into the cranial cavity—which might be conveniently denominated the cranial axis, from those in the white matter of hemispheres—is insisted on by *Kölliker*, who states all the former end in the ganglia above the crura cerebri; and this view accords well with the separation of corporeal and psychical operations, and with the absence of pain when the hemispheres are irritated.

We now proceed to briefly sketch that portion of the nervous system which fulfils the noblest function.

Man's Brain exceeds that of nearly all animals in weight, and all, without exception, in the preponderance of the hemispheres and the relative size of the brain and that of the nerves which issue from it. The average weight is 3 ℔, or nearly 50 oz., being about $\frac{1}{48}$ of the weight of the body, whereas that of the seal is said to weigh more, and in the canary and some other birds it forms $\frac{1}{24}$. In some fishes its proportion is said to be as 1 to 5,668. The brain of woman weighs usually about 5 oz. less than that of man. The brains of several individuals distinguished for exalted mental power have been weighed and found remarkable; but the proportion between the hemispheres and the cerebral nerves and other encephalic masses and the entire body would have afforded more valuable statistics. The accuracy of some of the following weights has been questioned: Cromwell, 100 oz.; Byron, 79; Cuvier, 64½; Dr. Abercrombie, 63; Dupuytren, 58; Lord Campbell, 53½. *Tiedemann* found the brains of two idiots respectively 20 ounces, 4 drachms; and 23 ounces, 4 drachms. In the transactions of the Anthropological Society, *Dr. Gore* furnishes an account of a female aged 42 years whose brain, without the membranes, weighed 2 ounces and 5 grains, it being the smallest mature human brain on record. She was 5 feet high, and her intellect was infantile. If the extent of the convoluted surface could be readily measured, it would probably indicate more surely the intellectual power. It has been computed that the surface of cerebrum and cerebellum measures 670 square inches. We have before mentioned that varieties of men differ more in the relative position of different portions of brain than in actual capacity of cranial cavity, and this has been lately demonstrated before the British Association by *Prof. Corbett* of Queen's College, Cork, who measured several aboriginal Australian crania by sealing up the foramina, and pouring in fine sand. He found the cranial capacity equal to the average European, and the cerebellar compartment not larger. In contrast with that of man, it may be noted that the horse's brain weighs about 19 ounces, and that of a whale, 75 feet long, but 70¼.

The Cerebral Convolutions are not symmetrical, with the exception of three—the ourlet, the island of *Reil*, and that internal to the olfactory nerve. The arrangement has the advantage of increasing the grey surface, and also that of the pia mater which feeds the brain. They are absent in all animals below rodentia, and thence become developed according to the amount of intelligence of the animal. The convolutions are not rolled up without evident plan, for *Leuret* and *Owen* have found primary grooves in all animals which have convolutions, and higher development is attained by more branching and greater depth. Those of the anterior lobe are medium-sized, and run forwards and outwards; those of the middle are large, white, and run directly outwards; those of the posterior lobe are very small, and run backwards and outwards. The great mass of white neurine enclosed in the convoluted grey cortex, consists of fibres diverging from the optic thalami and corpora striata, and of commissural fibres, which latter, so abundant in man, *Reil* called "the nerves of the internal senses."

Cerebral Commissures are longitudinal, transverse, and vertical. The following are longitudinal—the intergyral fibres, which unite convolutions just where the grey and white neurine come in contact; the ourlet, which runs along the edge of the corpus callosum, joining the hippocampi and anterior lobe; the fornix, which consists of fibres from the hippocampi, forming in front the anterior pillars which curve round the foramen of *Munro*, join the tænia and habenæ of pineal gland, and constitute the corpora albicantia in the circle of *Willis*. The tænia and habenæ are also, probably, longitudinally commissural. The transverse commissures are the corpus callosum, uniting one centrum ovale to the other; the anterior commissure, a white round cord between the corpora striata; the middle, which is a soft grey band joining the thalami; and lastly, the posterior, a white band which runs from one thalamus and nates, across the passage from the 3rd to the 4th ventricle, to those of the opposite side. The only vertical commissure is the septum lucidum, which dips between the lateral ventricles from corpus callosum to fornix. Anatomists describe 5 ventricles, namely, the two lateral, the third, fourth, and fifth, which latter only exists in fœtal life. Dropsical effusion distended this cavity in an interesting case recorded by the late *Dr. M'Dowel.* They are all lined by arachnoid, which bends in through the canal of *Bichat;* but, like another serous offset, the tunica vaginalis, the communication becomes occluded. We have elsewhere alluded to the cilia and corpora amylacea, which can be found in the ventricles. All these cavities were shown to communicate by the ingenious expedient of steeping the brain in water, and then freezing it. Under the epithelium is a coating of grey neurine, to extend the surface of which dynamic agent is their office.

Surgical injuries which expose the human brain, and experiments on animals, have proved the remarkable fact that the hemispheres have no common sensibility. Many animals will survive their entire removal; and with them disappear all mental powers, a deep trance, as it were, overcoming the individual, though common and special sensation and motion are retained. Their size is proportional to the mental endowments of animals, and of man at various ages or degrees of intellectual elevation ; and congenital or acquired defects of them are attended by proportional deficiency in the higher faculties. For the above reasons we must conclude that "The convolutions of the brain are the centres of intellectual actions, and are intimately associated with the mental phenomena of attention, association, and memory," an opinion shadowed forth by *Willis* in the seventeenth century. I regret that space does not permit me to sketch the outlines of psychology, which is but a department of physiological science. The writings of *Sir W. Hamilton*, *Sir H. Holland*, *Carpenter*, and *Noble*, contain the clearest and soundest views on the subject. *Dr. Wigan* started the ingenious theory that the mind was double, like the parts of the nervous system and the organs of the senses. It is well known that the lunatic—or, for a short period, the inattentive student—may pursue two trains of thought—never three, there being but two hemispheres. When, however, we close one eye or one ear, we do not lose the effect, owing to the free decussation between opposite sides ; and in man's brain, in which the commissures are so remarkably abundant, something similar may occur.

The Localization of Special Faculties was attempted by *Gall* and *Spurzheim*, and since their time by a few scientific enthusiasts and many pretenders. The main arguments for the opinion that each mental faculty has a special seat, which is the essential theory of phrenology, are as follows : 1. That other great physiological operations have their work apportioned to special organs ; thus, the stomach, liver, intestines, &c., each perform a peculiar office in the assimilation of food. 2. No two individuals are alike in propensities, talents, or other mental faculties, and various degrees of general cerebral development could not account for these peculiarities; and increase in size of various parts of the cerebral mass has been found after the death of persons remarkable for such speciality. 3. The energy of special mental faculties is increased or decreased at various ages, and in the insane alterations in one or more of the mental powers is vastly more frequent than in all of them together; and lastly, during dreams the action of some faculties, which are awake while others sleep, is advanced as a strong argument for the plurality of cerebral organs. It cannot be denied that there is much truth in many of these statements, but there is no proof that the seat of each faculty has been ascertained, or that we can judge of its development by examination of the cranium. And even if we could, the convexity only, and not the depth of the convolution could be estimated; and many parts, such as the inner surface and base of the cerebral hemispheres, are certainly out of reach. There is no line of demarcation between the convolutions to which are assigned special faculties, so that we can hardly suppose these would be so distinct; and any special convolution is not represented by a similar one on the opposite side. Of *Gall's* system, *Napoleon* justly remarked: "He ascribes to certain prominences propensities and crimes which do not exist in nature, but are the growth of society, and are merely conventional. What would the organ of theft effect if there were no property? the organ of drunkenness, if there were no spirituous liquors? or the organ of ambition, if there were no society?"

Sleep, a state in which one-third of our life is passed, is a subject full of interest to the physiologist. The brain, in common with all other organs, requires a period of repose, and then all consciousness and voluntary motion is suspended. Reflex actions, and many vital processes under the control of the ever-watchful organic nervous system, are still performed. The nature of sleep is hard to define, and *Sir H. Holland* says it "is not a unity of state, but a series of fluctuating conditions, of which no two moments are perhaps strictly alike." The capability of sleeping at any time exists in some individuals, as is related of Captain Barclay, who, during the time he was performing his favourite feat of walking 1000 miles in 1000 hours, could sleep the instant he lay down. Napoleon is said to have possessed a similar power. The duration of sleep varies much: Pichegru, the celebrated general, is said to have slept but 1 in 24 hours during a year's campaign; and John Hunter was satisfied with 5 hours habitually. Circulation is supposed to be more active during sleep, for the purpose either of increased nutrition or to restore molecular polarity. The darkness of night suggests the period of sleep, as man is essentially a diurnal animal, although the follies of fashionable life almost reverse his nature in this particular. Travellers tell us, too, that the inhabitants of Central Africa sleep during the day, and pursue their works of business or pleasure during the night.

Dreams while we sleep, and reveries while we are awake, seem due to the action of some portions of the cerebrum while others rest. They are examples of what might be termed "subjective cerebration," or they may be excited—as the author of that most pleasing work, "The Physiology of Common Life," suggests—by systemic sensations having some relation to the subject of the dream; for instance, the contact with any cold object will suggest a corpse; the rattling of the windows, a battle; or the smell of something burning, that the house is on fire. *Sir W. Hamilton* records, that having caused himself to be awakened at various times of the night, he invariably found himself dreaming. Many persons, especially those of a hypochondriacal or hysterical temperament, are susceptible of a condition termed somnambulism, and although in a dreamy state, they will perform many voluntary actions, reply to questions, and walk with caution enough to avoid obstacles. It is a phenomenon very analogous to mesmerism, a subject on which *Todd* and *Bowman* make the following judicious remarks:

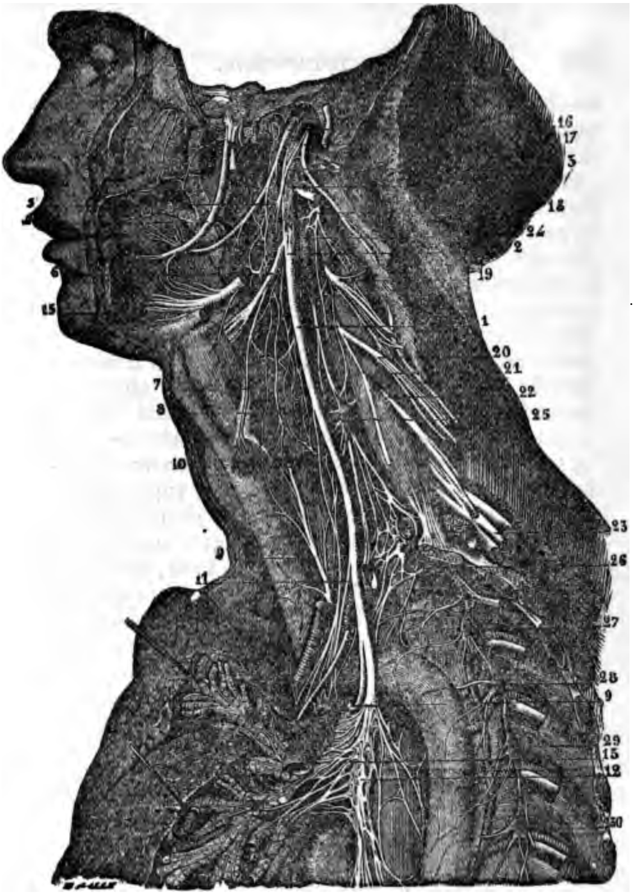
"A state remarkably analogous to this of somnambulism may be induced in persons of nervous temperament, which has been called the "mesmeric sleep," or trance. It requires for its production the apparent influence of another individual, who watches the person experimented on with an intent look, and makes certain movements before him which are called "passes." All persons are not susceptible of passing into this state, any more than they are of exhibiting the phenomenon of somnambulism. The same state of constitution which disposes to the latter is favorable to the former. Remarkable statements have been made, and confirmed by the testimony of a large number of observers, tending to imply that in these cases the faculties become exalted in an extraordinary manner, and that the individual acquires powers of a novel description, and even of a superhuman kind. It behoves all sober-minded persons to be slow to accept such statements as true, and, without impugning the veracity of the reporters, to inquire whether they do not rest more upon a misinterpretation than upon a misrepresentation of facts. The polar force of the mental nervous centres may, in this peculiar state, be so affected as to favour the development of subjective phenomena, which, it is evident, may assume particular forms under the influence of impressions made from time to time upon the senses. The ravings of a delirious or of a lunatic patient, often take a particular direction under the influence of a question or remark let fall by some bystander; it is not unlikely that persons, with a mental bias for the marvellous, might discover in such patients quite as much evidence of superhuman power as has been adduced by the mesmerists.

"We cannot avoid remarking how much it is to be lamented that inquiries of so delicate a nature, affecting the very confines between mind and matter, should have usually fallen into the hands of persons ill qualified for such pursuits, either by mental constitution or by previous experience in the study of subjects involving both physical and metaphysical knowledge. Little is to be expected in such difficult researches from dilettanti of either sex; much less from those whose excessive zeal for novelty and notoriety must necessarily cast suspicion on their statements. Nor can we hope that truth can be elicited from experiments and observations which are made before the public gaze, with more of the characters of a theatrical exhibition than of a sober philosophical investigation." With regard to phantasies, *Müller* tells us, "When a person who is not insane sees spectres and believes them to be real, his intellect must be imperfectly exercised;" and we must also remember that "mysteries are not necessarily miracles."

THE SYMPATHETIC

Nervous system—also termed that of "organic life" by *Bichat*, in contradistinction to the cerebro-spinal, or system of "animal life"—consists of a chain of ganglia placed along the vertebral column, and all connected by gelatinous nerve filaments. The dorsal ganglia have the most numerous spinal filaments. The chains of opposite sides are united on the anterior communicating artery—where *Ribes* discovered a ganglion—by the solar plexus, and below by the ganglion impar on the sacrum. The sympathetic also aids in forming the ganglia on the cerebral nerves, and those on the posterior roots of the spinal which have been alluded to. The account of the histology of nervous matter which we have already given, includes that of the ganglia and branches of which we are now speaking. As an example of the manner in which the branches are distributed, we shall examine the superior cervical ganglion. It is probably the largest in the body, measuring about two inches in length, and lying on the first three vertebræ. Its branches are—1. Ascending round the internal carotid artery to the cavernous sinus, where they intimately unite with the abducens nerve and some cranial ganglia. As in other positions where they accompany an artery, the twigs entwine closely, "hederæ admodum," and from their softness were termed by *Scarpa* "nervi molles." 2. Descending to the next ganglion. 3. External, communicating with spinal nerves and their plexus, as all ganglia do. 4. Laryngeal. 5. Pharyngeal. 6. Superior cardiac, which, with those from the middle and inferior ganglia, aid in forming the cardiac plexuses. Organs are usually supplied by the ganglia above them, not by those in their own vicinity, as in the case of the heart, abdominal viscera, testes, &c. The accessory ganglia in and about the heart, and the use attributed to them, have been mentioned in treating of that organ. Occasionally the chain of ganglia seems interrupted by the last dorsal and first lumbar having no communicating filament between them. When an organ becomes increased in size, the sympathetic nerves of it enlarge proportionally, as may be learned by comparing those of the virgin and pregnant wombs. Microscopical investigations are every year adding to the number of ganglia which have of late been found in the tissue of the heart, stomach, intestines, kidney, uterus, &c. It is doubtful if any filaments pass into the limbs, but prabably their arteries may carry some down. The system has been demonstrated in all vertebrates save the cyclostomatous fishes, in which the vagus probably performs its functions.

The Function of the sympathetic is not easy to determine, as so many cerebro-spinal nerves communicate with it. No direct cerebro-spinal nerves reach the in-



Sympathetic, and Cerebro-Spinal Nerves of the Head, Neck, and Thorax.

1. *Pneumogastric.* 2. *Its laryngeal ganglion (Sir A. Cooper).* 3. *Pharyngeal branch of spinal accessory.* 4. *Gustatory.* 5. *Internal carotid.* 6. *Superior laryngeal.* 7. *Its crico-thyroid branch.* 8. *Pharyngeal plexus.* 9. *Left recurrent.* 10 *and* 11. *Cardiac branches of pneumogastric.* 12. *Left pneumogastric in front of œsophagus.* 13. *Posterior pulmonary plexus.* 15. *Lingual.* 16. *Glosso-pharyngeal.* 17. *Spinal accessory.* 18, 19, 20. *Second, third, and fourth cervical.* 21. *Phrenic.* 22. *Fifth cervical.* 23. *Brachial plexus.* 24, 25, 26. *Superior, middle, and inferior cervical ganglia.* 27, 28, 29, 30. *First, second, third, and fourth dorsal ganglia.*

testines, yet irritation of the solar plexus will produce vigorous peristaltic movements, except in the tench, as the muscular fibres of the alimentary canal are striated; and their sensibility is shown by the torture which overdistension of the colon produces. It cannot, however, be confidently asserted that these effects are due to the true sympathetic, as it derives many nerve-tubes from the posterior roots of the corresponding spinal nerves, irritation of which will produce identical results. Sensitive impressions, unless intense, are not felt, or are slowly carried along sympathetic fibres, and it was once thought that their purpose was "to cut off sensations." Motor influence is also slowly conducted, and thus what is called rhythmical contraction is produced. As implied by the name—which notwithstanding so many objections has so long adhered to it, it was once supposed to be the exclusive seat of sympathies, harmonizing all nervous actions, and its free communications gave support to the notion. The discovery, however, in 1727, by *Pourfour du Petit*, that section of the cervical portion gave rise to suffused conjunctiva, which protruded into what is called "the haw" and contracted pupil, led the way in ascertaining its most important functions. We have already alluded to the experiments which demonstrated its influence on animal heat and the secretion from glands (see pages 173 and 179); and *Brown-Séquard* has obtained scarcely less important results as regards its vasomotive action and consequent control over nutrition and other organic processes. He found that placing one hand in ice-cold water lowered the temperature of the other, although no great depreciation took place in the system at large; that this was due to the influence of the sympathetic he inferred from the fact, that stimulation of that nerve in the neck produces contraction of the vessels and diminished temperature, or exactly opposite results to those produced by section of it. A still more convincing experiment was suggested and performed by the reviewer of the works of *Brown-Séquard* in the "Natural History Review," July, 1861. A bat's wing is placed in the field of a microscope, and an artery in it accurately measured with the eye-piece micrometer; now if ice be applied to the opposite wing the vessel can be seen to contract or even close completely. The discovery of the constriction of blood-vessels by stimulation of the sympathetic was made also simultaneously by *Brown-Séquard*, *Bernard*, and *Dr. A. Waller*.

The occurrences which these physiologists have observed to take place when the cervical portion of sympathetic is divided, and when it is stimulated by galvanism, are here compared:

SECTION.	GALVANIZATION.
Pupil contracts.	Pupil dilates.
Eyelids, including nictitating membrane, partially close.	Eyelids partially open.
Eye shrinks.	Eye protrudes.
Mucus increases	Mucus decreases.
Vessels dilate, flow of blood increases.	Vessels contract, flow of blood decreases.
Temperature increases.	Temperature decreases.
Sensibility and irritability increase and last longer after death	Sensibility and irritability decrease and disappear sooner after death.
Strychnia causes convulsions more readily.	Strychnia causes convulsions less readily.
Muscular galvanic current is stronger.	Muscular galvanic current is weaker.
Rigor mortis comes later, lasts longer.	Rigor mortis comes sooner, lasts less time.
Putrefaction comes later.	Putrefaction comes sooner.
Injection of arterial blood restores contractility for a longer time.	Injection of arterial blood restores contractility for a shorter time.

To account for the increased action which occurs when the sympathetic is injured, it is suggested that it may have an inhibitory or preventive function. Section of the spinal cord leads to effects quite similar to those produced by that of the sympathetic, and it is not certain whether this is due to fibres of this system passing up through the cord, or to the action of that nervous centre itself. If one-half of the cord be divided, the limb on the same side has its vessels soon dilated, its sensibility augmented, and its temperature increased, so that the vaso-motor fibres do not decussate till the pyramids, where the ordinary motors also cross. Again, *Lister* has shown that irritation of the cord in the frog will produce contractions of the vessels of the web, and the same effect may be produced by galvanising the anterior roots of the sciatic nerve within the canal of the large edible frog. Division of the roots produces dilatation of the vessels, increased circulation, and more rapid absorption of poisons. Some recent experiments show, that section of the cerebro-spinal nerves which join the sympathetic produces the effects upon the eye usually assigned to section of the sympathetic; and if the latter nerve be divided between ganglia, no effect on the eye follows. *Brown-Séquard* believes that irritation of a centripetal nerve may produce either constriction or enlargement of remote vessels; and I quote from him the following passage, as showing the great pathological interest of these inquiries: "Suppose a worm in the bowels irritating their centripetal nerve fibres, the irritation is propagated to the spinal cord, which reflects it upon the roots of the cervical sympathetic nerve, by which it reaches the blood-vessels of the retina, produces their contraction, and, as a consequence of this cause of diminution in the amount of blood, an amaurosis. If, instead of the reflex action on the blood-vessels there is an action on the tissues, as in the case of the experiments of *Bernard*, the blood-vessels dilate and more blood passes through them. The cornea, for instance, is irritated; its centripetal nerve fibres transmit the irritation to the pons varolii, which reflects it upon the retina, the lacrymal gland, the conjunctive, &c.; more blood is attracted by all these parts, their blood-vessels dilate, and the consequences of a greater amount of blood becomes manifest—increase of tears, photophobia, &c." *Du Bois Reymond* assigns as the cause of hemicrania, from which he suffers intensely, tetanic contraction of the arteries of the affected side produced by the sympathetic.

We shall return to this subject when reviewing the pathology of innervation.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. What is the composition of brain matter, and does it vary with the superiority of its function?
2. Describe the structure of a nerve-tube.
3. Do nerves anastomose, and in what way do they terminate?
4. What proofs can you offer that divided nerves re-unite?
5. Enumerate the electric fishes, and show that the agent they emit is identical with electricity set free by ordinary means.
6. State the uses of the membranes of the cerebro-spinal axis, noting any differences which occur in different parts of it.
7. Describe the external form of the cord.
8. Mention any experiments which show the functions of the cord.
9. What are the functions of the roots of the spinal cord, and how can they be shown?
10. What functions have been assigned to the cerebellum?
11. Enumerate the cranial ganglia and the commissures between them.
12. What functions have been assigned to the sympathetic system?

SENIOR.

1. Sketch the histology of dynamic neurine.
2. Contrast the position and structure of gelatinous and cylindrical nerve-tubes.
3. Explain the structure and uses of a ganglion and a plexus.
4. What theories of nervous force have been started, and in what particulars do it and electricity seem to differ and to agree?
5. Say what you know of the luminosity of animal bodies.
6. Are the quantity of blood and superincumbent pressure of the brain the same at all times? Give any facts and arguments which bear on the questions.
7. Sketch fully the appearances seen upon a transverse section of the cord visibly and microscopically.

8. Explain and illustrate reflex nervous phenomena in health and disease.
9. What are the effects of section of one half of the spinal cord?
10. Describe the structure and functions of the medulla oblongata.
11. Adduce as many arguments as you can for and against phrenology.
12. Enumerate and explain the effects which follow section of the cervical portion of the sympathetic system? What other section is said to produce similar effects on the eye?

MOTION

Is exhibited in animal bodies, usually in three ways—molecular, ciliary, and muscular; the first of which is common to the vegetable and inorganic kingdoms, and was discovered by *Robert Brown*, after whom it is often named. It is easily seen when fine particles are suspended in a fluid; gamboge when rubbed up in water shows it readily. The movements called cyclosis in the characeæ—which are, however, very regular and not influenced by evaporation—and that of the pollen of plants, may be of this nature. It has been said to be due to currents produced by evaporation (it will sometimes, however, go on in vessels hermetically sealed, or in oil which is not volatile), by the light heating the surface of the fluid, by vibrations produced in the room where the vessels lie, or by gravitation. The movements of the blood-cells, and of the fibres of *Jacob's* membrane, are sometimes regarded as molecular.

Ciliary Motion may be seen on the lachrymal, nasal, and bronchial surfaces, on that of the Fallopian tubes, and for a few lines on the peritoneum where they end in the fimbriæ, and on the minute seminiferous and uriniferous passages. Cilia are much more abundant in the lower forms of animal life, serving for the introduction of nutritive matter and the removal of that which is effete. The only serous membrane which is ciliated in man is the arachnoid in the ventricles; but the pericardium, peritoneum, &c., are ciliated in reptiles. Cilia are about $\frac{1}{1000}$ in length, are thickly set in rows on columnar epithelium. Those of the tracheal cells are shown upon p. 152. Their motion is very remarkable when watched by the microscope; they wave usually towards orifices, and all bend at once, like corn when affected by the wind, sometimes they sweep round, like the feathering of an oar. A little powdered charcoal makes their movements more apparent. They move long after muscular motion has ceased; thus, the tracheal cilia of man have been seen to wave 7 days after death, and those of the œsophagus of the turtle 19 days, when the body was becoming putrid. Ciliary motion is best preserved by a uniform degree of moisture and temperature, and continues longest in blood—whereas bile checks it at once. It appears to be independent of muscular or nervous force, as it remains so long after their departure, and even upon one separated epithelial cell; and electricity, prussic acid, or opium, do not affect it. Spermatozoa are regarded by some as cells with single cilia. The enlargement and contraction of the cell by osmose is probably the cause of the motion of the cilia; and such motions in plants as the folding of the leaves of the sensitive plant, the bending of the stamens of the barberry, and the closing of the venus's fly-trap, are believed to be analogous.

Locomotion is a faculty possessed by nearly all animals, and there is nothing analogous among plants. In man, the organs concerned in this function are either active—as the muscles, under the command of the cerebro-spinal system—or passive, including the bones, with the ligaments which bind them together; the cartilages, which render their ends smooth and elastic; the synovial membranes, which obviate friction; and the areolar and adipose tissues, which connect, yet separate and pack all the apparatus of motion.

Fibrous Tissue, which composes all ligaments, tendons, fasciæ, and areolar matter, is of two kinds—1. White, inelastic threads placed parallel to each other, like a skein of silk, and loosely connected by areolar tissue. Acetic acid swells and softens the fibres, and, by bringing nuclei into view, shows that it was developed in cells arranged lineally. Gelatin is produced by boiling. Its physical properties are, a glistening silvery whiteness, flexibility, and such tenacity that 1,000 ℔ force is required to rupture the tendo achillis. The strength of muscle is, however, greater during life. This tissue is but slightly vascular and sensitive during health, but its unyielding nature gives rise to great pain under inflammation. It is used in the construction of funicular, fascicular, or capsular ligaments, to bind bones together; in tendons, through which muscles act with greater efficacy, while bulk is reduced; in aponeuroses, which confine muscles; in the coating of bone and fibro-cartilage; and in protecting the brain (dura mater), eye (sclerotic), testis (tunica albuginea), &c. Its reparation is accomplished by a soft blastema, which gradually assumes the fibrous character.

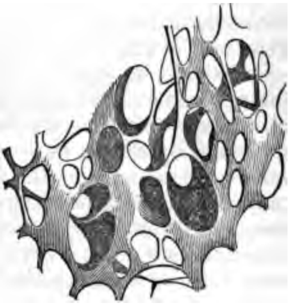
White Fibrous Tissue.

2. Yellow elastic tissue is made up of finer fibres, ranging from $\frac{1}{10000}$ to $\frac{1}{5000}$, with sharp, distinct margins, and having a tendency to divide transversely, as if made up of cells. These more readily split up into 2 or 3 smaller threads which, however, exceed the diameter of the primary fibre, and which curl back on themselves, like celery dressed for table. Prolonged boiling, acids, or the digestive or putrefactive processes, but slightly affect this tissue. From being stained yellow by nitric

acid, and red by *Millon's* reagent, it is regarded as intermediate between syntonin and gelatin, some chemists assigning the formula $C_{48} H_{38} N_6 O_{16}$, or protein and 2 equivalents of water. Nothing is known of its development or reproduction. It possesses the valuable property of elasticity, which produces force always antagonistic and secondary to muscular power. It is nearly as elastic as india-rubber, and regains this property on being moistened, although dried up for months. The ligamenta subflava, middle coat of arteries, vocal cords, crico-thyroid, thyro-hyoid, and stylo-hyoid ligaments, epiglottis, the tissue between the tracheal rings and the calceo-scaphoid ligament, which gives the spring to the foot, are examples of it. In quadrupeds the abdominal walls and the ligamentum nuchæ, which supports the head of a grazing animal more constantly than muscles could, contain much of it.

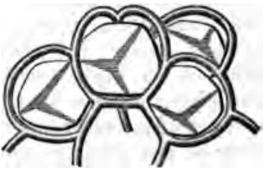
Yellow Elastic Tissue.

Areolar Tissue is the most universal of the constituents of the body. As the "superficial facia," it spreads under the skin, tying it to deeper parts, and giving a nidus for fat; it separates, yet connects muscles and other parts—hence named conjunctival by *Henle;* as the parenchyma, it constitutes the matrix of most solid organs; and, lastly, forms pads for the protection of,


Areolar Tissue.

and smooth capsules for the free motion of such organs as the eye, which *O'Ferrall* has shown is enveloped in an exquisite structure he has named "tunica vaginalis oculi." When inflated and dried, this tissue is seen to consist of spaces freely communicating—hence the impropriety of the term "cellular," given to it by *W. Hunter*. Its areolæ permit the transmission of air (emphysema), serum, (anasarca), blood (ecchymosis), and other fluids, over a great extent of surface. It consists of threads of the white and yellow elements woven most inextricably together, but distinguishable by acetic acid, which exhibits nuclei in the former; and the tissue is generated by cells elongating, and joining in lines. Like both kinds of fibrous tissue, it is very slightly vascular, although many vessels pass through it en route to the skin; and any strangulation of them, as in anthax, will cause death of the latter. Its toughness, extensibility, and elasticity are admirably proportioned to mobility of each part—thus, it is loose and abundant in the axilla, orbit, and by the sides of the rectum; almost absent in firm glands—heart, brain, bone, or teeth; and most elastic about joints and the abdomen.

Fat, the chemistry of which we have treated of already, is contained abundantly in the meshes of the areolar tissue. It is contained in cells from $\frac{1}{300}$ to $\frac{1}{800}$ in diameter—spheroid if single, or polyhedral by mutual pressure. The cell-wall is extremely thin, and being moistened by serum, as *Paget* remarks, does not allow the fat to exude. Capillaries are looped round each cell. Adipose and areolar tissues are not always co-existent in equal amount; in canceli of bone, mesentery, Haversian masses, &c., we find fat with scarcely any areolar tissue, the reverse being the case in the eye-lids, about the penis, scrotum,

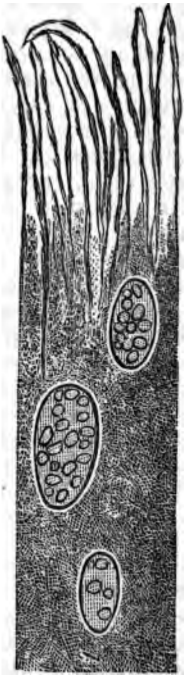


Fat-cells surrounded by loops of Capillaries.

and bladder, and along the median line of the body. It seems to have no proper nerves or lymphatics. It is mechanically useful in padding exposed situations, its particles freely moving, and it obviates pressure, like a water cushion, and in retaining the heat within the body, for which reason it is most abundant externally in early life, and in aquatic mammals, as the whale, seal, &c. In old age and corpulent persons it heaps about the viscera, as the heart, liver, mesentery. It lessons the brittleness of the bones, and forms cushions in many joints. Its calorific office has been before considered.

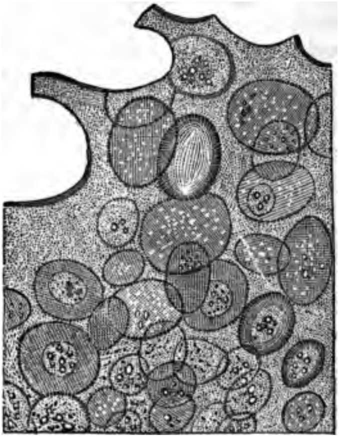
Cartilage may be "temporary" and afterwards become bone; or "permanent," which may be subdivided into "articular," covering the ends of bones, or "fibro-cartilage," which builds up such organs as the external ear, nose, larynx, &c. Simple cartilage, as that which encrusts the end of any of the long bones, consists of oval cells with numerous granular nuclei, such as represented in the lower part of the next figure, embedded in a structureless matrix or hyaline substance. *Prof. Beale* regards this hyaline substance merely as the walls of the cells, proving the analogy between cartilage and such tissues as epithelium, which plainly are wholly cellular. The cells are often grouped in twos and threes, and are flatter towards the surface. It is covered by a delicate film of synovial epithelium, as demonstrated by *Henle*, especially in the fœtus. This covering and the "circulus articuli vasculosus" of *W. Hunter* supply them freely with blood. It is of a pearly white colour, becoming yellow when dry.

Fibro-cartilage is often membraniform, tough, elastic, and covered by a membrane, the perichondrium, which, like periosteum, conducts nutrient vessels. Inter-articular fibro-cartilages, in which the fibrous element abounds, are found in the following joints—knee, temporo-maxillary, sterno-clavicular, that between ulna and cuneiform, vertebræ and heads of ribs, and sometimes between acromion and clavicle. They are of a discoid or meniscoid shape, and afford a moveable and concave surface for the rounded bone. The glenoid and cotyloid ligaments surrounding the brim of the glenoid cavity and acetabulum, and the posterior tibio-fibular ligament, are of similar structure. As we shall find hereafter, the elastic laminæ of the cornea, capsule of lens, and zona pellucida of the ovum, present many analogies to the hyaline base of cartilage. The microscope has not yet detected vessels in cartilage large enough to carry the red cells; but in temporary cartilage, especially, there are vascular canals transmitting the plasma of the blood, and as the vessels of the synovial membrane and bone form many vascular loops in their immediate vicinity, we cannot call them "extra-vascular." *Toynbee*, however, states that cartilage is separated from bone by an impenetrable lamella. We owe all our knowledge of the pathology of the articular cartilages to the masterly investigations of *Prof. Redfern*, now of Queen's College, Belfast. The changes which occur in what is usually termed ulceration, but which is really a process of abnormal nutrition, he describes as follows: "They consist in the gradual enlargement and rounding of the cells which become filled with a multitude of corpuscles, which, on the bursting of the cells, are discharged into the texture, and



Vertical Section of the Patellar Cartilage, showing the Cells, and the splitting of the hyaline mass at the surface when diseased, after Redfern.

removed from it by changes to be afterwards shown. The hyaline substance splits into bands and fibres, and is subsequently disintegrated and removed from the part." These two figures—selected, with his kind permission, from the great number which illustrate *Prof. Redfern's* work—exhibit the changes which occur. In the first, the splitting into fibres has taken place. In the second, the cells are as numerous as in temporary cartilage, and some have burst, leaving spaces in the hyaline substance. In many instances he has shown the "conversion of the nuclei into fatty granules and globules." We shall again allude to these most important discoveries when describing inflammation.



Multiplied and Enlarged Cells in Cartilage, after Redfern.

Serous Sacs envelop all organs which move in performing their functions; and synovial membrane, which is of the same nature, surround bones where they are joined together, or lie about tendons where they require to move easily over a bony point. *Bichat* believed that serous membranes were of use in isolating any disease attacking an organ. Each sac consists of two portions—a parietal, which lines the walls of the cavity; and a visceral, which coats the part within, but becomes continuous at several points, especially where the vessels enter. The cavity is filled with a halitus poured out by the membrane, and is closed—except in the case of the peritoneum, into which the genital mucous surface opens at the end of the fallopian tube. The pleuræ, pericardium, and arachnoid have fibrous coats outside them; but the tunica vaginalis, a process pushed down from the peritoneum, has the fibrous capsule nearer to the organ invested, the testis.

The Synovial Membranes cover the ends of the bones, the ligaments, and, according to *Henle*, the cartilage. They form vascular fringes, which some believe secrete the synovia, which was once supposed to be done by those masses of fat in some joints, termed the Haversian glands. The tendons at the wrist and fingers, ankle and toes, are clothed by synovial sheaths called thecæ. Bursæ mucosæ is the inappropriate term under which these synovial sacs about joints or exposed points are described, because *Abernethy* believed them to be mucous. Some of them are unilocular, some multilocular, and all of them are merely spaces of areolar tissue enlarged and not lined by epithelium. They may be congenital or adventitious—as over the spine of those who carry weights, and upon the prominent points of club-foot, distorted toes (bunions), and other deformities. The synovial membrane of the knee is the only one into which *Kölliker* could trace nerves. Synovia is a thick, colourless fluid, very like the colloid matter found in some morbid growths. It contains much albumen—being named from its resemblance to white of egg—1 per cent. of oil and water, which is less in quantity if the joint be much used. The joints of stall-fed and grazing cattle readily show this difference. Its use is to prevent friction, by filling the inequalities on the articular surface. Serous and synovial membranes consist of a layer of polygonal tesselated cells, lying on a basement layer. The epithelium of synovial membrane on a convex surface is often columnar. The mechanism of the joints of the human skeleton will be understood by studying the classification on the following page.

	Nature.	Motions.	Examples.
DIARTHROSIS OR MOVABLE JOINTS.			
ARTHRODIA	Plane surfaces.	Gliding.	Articular processes of vertebræ.
ENARTHROSIS	Ball and socket, or convex and concave surfaces.	Flexion, extension, adduction, abduction, rotation, and their multiple circumduction.	Hip.
GINGLYMUS	Hinge.	Flexion and extension.	Elbow.
TROCHOIDES	A pivot rolling in a ring.	Rotation.	Atlanto-axoid.
AMPHIARTHROSIS OR MIXED JOINT.			
SYMPHYSIS.	Joined by elastic tissue.	Slight yielding.	Interpubic.
SYNCHONDROSIS	Joined by cartilage.	Slight yielding.	Sacro-iliac.
SYNDESMOSIS	Joined by ligament.	Slight separation.	Transverse processes of vertebræ.
SYSSARCOSIS	Joined by muscle.	Gliding.	Scapula and trunk.
SYNARTHROSIS OR IMMOVABLE JOINT.			
SUTURA:			
Dentata	Toothed.	..	Interparietal.
Squamosa	Over-lapped.	..	Temporo-parietal.
Limbosa	Where both bones are bevelled, but at different points	..	Parieto-frontal.
HARMONIA	Plane edges.	..	Facial bones.
GOMPHOSIS	As a nail in its socket.	..	Teeth.
SCHINDYLESIS	One split to receive the other.	..	Vomer.

Into the movable joints all the structures we have hitherto described enter, and, in addition, the muscles and their tendons which lie around serve to further protect them, and to remove the loose synovial membrane from the cavity of the articulation during its movements. In the shoulder also the muscles are the main agents for preserving the bones in apposition.

Atmospheric pressure is in some joints a powerful retaining force—as in the hip, where it is equivalent to over 30℔. It will hold together the bones after all ligaments are divided; but if a hole be drilled from the pelvic surfaces, the equilibrium is restored, and the bones fall asunder, as *Weber* demonstrated. The bones will also separate in the exhausted air-pump receiver; and the weakness at the hips perceived by travellers ascending high mountains is due to this cause, as well as the diminished muscular power, oxygen being deficient. The force at the hip-joint is sufficient to relieve us of the weight of the thigh in walking, one limb being suspended while the other is on the ground.

The Neuro-Skeleton, which is situated in the interior of vertebrates, and the dermo-skeleton, which a few others possess like a coating of mail on their surface, are composed of the substance we term bone. Its physical properties are well known; it is hard and dense, yet elastic, white, and opaque. Bone is said to be twice as strong as oak, 5000 ℔ weight being required to crush 1 square inch. It is composed of two classes of material united, probably in definitive chemical equivalents: 1. The earthy, which may be removed by steeping a bone in dilute nitric acid. The bone still retains its shape, but, losing its opacity and density, becomes semi-transparent, and so flexible that a knot can be tied upon it. 2. The organic matter, which incineration will destroy; if burned with free exposure to air the bone becomes white—or black if air be excluded, the carbon not being oxidised. In this condition it has lost cohesion and elasticity, and can be readily powdered. Prolonged boiling, especially under the higher temperature which increased pressure produces, as in *Papin's* digester, will also remove the organic matter, which is termed ostein or gelatin. The relative proportion is said by many analysts to differ in early, middle, and advanced life as follows:

	Child.	Adult.	Old Man.
Animal	47·20	20·18	12.2
Earthy	48·48	74·84	84·1

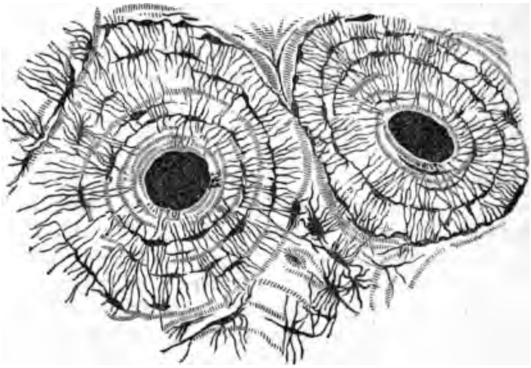
However, these statements have been questioned by *Dr. Rees*, who thinks bone is composed of definite quantities at all ages, and the varying density results merely from different arrangement of its particles at each period—and with these views I am strongly inclined to agree. The quantity of earthy matter is various in many bones, the petrous portion of temporal, long bones of lower extremity, of upper, pelvis, and trunk, each containing it in the order enumerated, which is also very much the order of the amount of work each is destined to do. Another fact indicating the uniform composition of bone is, that those dug from Pompeii and fossil bones yield the same proportions as the most recent. *Gimbernat* is said to have made soup from the tooth of a mastodon. The following analysis exhibits the proportion of various salts:

Animal matter	31·11
Phosphate of lime	59·14
Fluoride of calcium	2·23
Carbonate of lime	6·32
Phosphate of magnesia	1·20

More than half of bone is, then, phosphate of lime—a salt first found by *Gahn*. Bones effervesce in acids, owing to the carbonate they contain. Fluoride of calcium, which *Von Bibra* discovered, exists most freely in teeth, the petrous portion of temporal and fossil bones, as may be shown by acting on them with sulphuric acid, when the hydrofluoric acid evolved will dissolve glass. This reaction can be produced by phosphoric acid combined with water, according to *Dr. Rees.* *Carpenter* states that the hardness of bone does not depend on the relative proportion of salts and gelatin, as the bones of fish contain as much salts as those of deer and sheep.

The periosteum is the tough fibrous membrane which invests the outer surface of bone, conducts its vessels, joins the epiphyses, which are separate in early life, and diffuses the power of muscles over a greater surface. The endosteum is a thinner and more vascular web, which supports the medulla or fat in the canals of long bones or the cancelli of spongy ones, and which accompanies the vessels through the Haversian canals. The marrow is either of a red or yellow colour, and is placed within the medullary canal because of its lightness and fluidity, which disperses shocks equally over the whole bone. The fat is also stored here for calorific use.

The Minute Anatomy of bone has been a much debated subject. *Havers* and *Duhamel* approached the truth nearly when they said it was laminated in structure; *Scarpa* believed it cellular, *Bichat* fibrous, *Tomes* granular, and *Gagliardi* fancifully described it as plates pegged together by little nails, which we now recognise as the lacunæ, but which appeared to him solid. Its true structure, as determined by recent microscopical investigations, is briefly as follows: The laminæ are arranged round an Haversian canal, and between them lie small stellate cells which are termed lacunæ, their projections being continuous with the canaliculi or minute tubes which join them with each other and with the Haversian canals. The lacunæ bear a remarkably constant proportion to the size of the blood-cells of the species, but not to the magnitude of the animal itself. The canals run with the long axis of the bone, and are readily seen on transverse section, with the laminæ, lacunæ, and canaliculi about them, arranged in what is called "an Haversian system," two of which are here represented. The canals vary from $\frac{1}{200}$ to $\frac{1}{2000}$ in diameter, and are either arterial or venous, which latter coalesce into the veins which emerge from the surface, and which are remarkable for their number, absence of an outer coat, and their free anastomosis. *Dr. Benson*, now Professor of Medicine in the Royal College of Surgeons, stated, in his admirable account of osseous tissue in Todd's Cyclopedia, that the veins have but one coat, and this so closely adherent to the sides of the canal that they could never alter their shape or size ; and this seems to me to account for the diffuse character of inflammation when it attacks them, for they cannot be readily occluded by lymph. *Breschet* demonstrated those of the cranial bones, which are termed diploic, by filing off the outer table. The arteries of bones are of 3 sizes—the largest named the nutritious, which enter about the centre of the long bones, and run downwards in all bones save the femur ulna and radius, in which



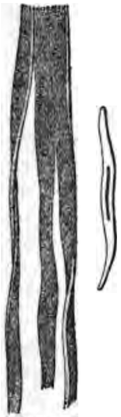
Two Haversian Systems, consisting of canal, surrounding laminæ, lacunæ, and canaliculi.

bones only the lower epiphyses are the last to unite; the medium-sized enter at the articular ends; and the smallest from every point of the periosteal surface. Osseous tissue is either compact, as in the shafts of long bones, where all its elements are closely condensed; or spongy, as in the articular ends, where, instead of one medullary canal, each of the cancelli must be regarded as such.

The Uses of Bones are numerous, for besides forming, as we shall fully consider farther on, the passive organs of locomotion, they give shape to the whole frame, and protect the viscera, organs of sense, and, above all, the cerebro-spinal axis. How admirable the mechanical construction of the skeleton is may be learned from the following example adduced by *Mayo:* "In the cranium especially physiologists delight to notice the strength derived from its arched form; the partial thickening of its most exposed and prominent parts; its texture strengthened by being wrought in 3 layers of varying density; its sutures which concur with the last-named provision in diminishing its brittleness, and their well-known squamous configuration at the side of the head, enabling the sphenoid and temporal bones to resist the pressure outwards at that part when the vertex is forcibly struck." The advantages derived from the hollowness of bones are—1. A given quantity of material will make a stronger pillar if wrought into a tube than into a solid cylinder. It is sometimes incorrectly conceived that a hollow bone is stronger than a solid one of the same diameter. 2. A greater surface for attachments. 3. Lightness. 4. Storage for calorific fat, the fluidity of which disperses any shock the bone receives over all the surface. In birds, in addition, a vast respiratory surface is produced by air being admitted, and by condensation or rarefaction of it their body becomes specifically heavier or lighter. By weighing carefully the bones of a skeleton, very remarkable relations may be discovered between their weight— thus, the bones above the central point of the body, which is near the umbilicus, weigh precisely as much as those below that point. The bones of the hand are ⅛ the weight and ⅕ the length of those of the whole arm; the hand weighs just half as much as the foot; and lastly, each bone of the right side, including those of the head, is heavier than the corresponding left one. Many other proportions can be discovered, and they hold good in lower animals, and might be of use in arranging skeletons.

The Development of bone is usually said to have 3 stages, which *Haller* described as the gelatinous, cartilaginous, and osseous; but in the case of the cranial bones and some others, the second of these does not exist, the bone being formed between fibrous membranes—one of which, the dura mater, we often find converted into bony plates like the osseous falx and tentorium of some animals. The first centre of ossification appears in the clavicle at about the 4th week, and others follow in the following order: lower jaw, ribs, femur, humerus, tibia, vertebræ, pelvis, tarsus, &c. In the long bones the primary point forms the shaft or "diaphysis," and one at each end develops the "epiphyses," which, in the case of the lower extremity of the femur, remains disunited till the 25th year. The tubercles or processes are often produced separately, and are termed "apophyses."—Growth in the long axis afterwards takes place in the layer of epiphysary cartilage, especially at its surface towards the shaft. *Hunter* showed this by inserting two grains of shot, at a measured distance, apart in the tibia of a young pig, which he found afterwards had scarcely separated, although the bone had grown much longer. However, such bones as the clavicle and lower jaw, which have no epiphysary cartilages, must grow by interstitial deposit.

Bones grow in thickness by layers being laid down concentrically by the periosteum and endosteum, in a way not unlike the exogenous vegetable stem, as demonstrated by *Duhamel*, who placed a silver ring round a growing bone and found it afterwards almost sunk into the medullary canal, which is not formed when bones are at first developed. The same fact was beautifully exhibited by *Belchier*, who discovered that the bones of animals could be stained by any coloured matter it was fed on. He was dining with a calico-printer, and remarked the bones of a leg of pork to be quite red, the animal having taken food containing madder. This dye circulating with the blood became laid down with the phosphate of lime, for which it has chemical affinity, in the vicinity of the vessels, a crimson circle forming round each Haversian canal. If an animal, especially a growing one, be fed alternately upon food with madder and then without it, alternate rings of red and white will be seen on transverse sections. Bone is produced with surprising rapidity in disease in the human subject; and among lower animals, the fossil Irish elk is calculated by *Prof. Owen* to have cast off and renewed 80 ℔s. of osseous matter in its antlers each year. The admirable process for the reparation of injured bone I will consider hereafter.

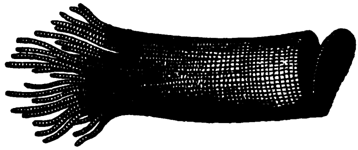


Fibres of unstriped muscle, and a muscle cell.

MUSCULAR TISSUE

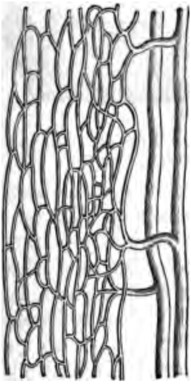
Is of two kinds, voluntary and involuntary, the latter of which, being the more simple, we shall first describe. It constitutes what are often termed the "muscles of organic life," as those of the digestive tract, the trachea and bronchi, the uterus, bladder, and urethra; such ducts as the ureter, vas deferens, and lastly those structures in the skin which will produce the condition termed cutis anserina. It consists of pale, flat bands showing indistinct granules, and oval nucleated cells which destroy the parallelism of the edges. The average width is $\frac{1}{2800}$. *Bowman* states the fibres do not interlace, as generally believed, but the bulgings at the cells make them appear to do so when not fully in focus. There are two tests which indicate the presence of this "unstriped" muscular fibre—namely, acetic acid, which develops the nuclei, and a galvanic current which produces movements propagated slowly along the whole length. *Kölliker* discovered another kind of involuntarily contractile tissue in the trabeculæ of spleen, prostate, coats of arteries, &c., and named it "muscle-cells," which are spindle-shaped, with a nucleus very evident. They are probably but an earlier stage of the unstriped fibre, beside which it is placed in the preceding figure.

2. Voluntary muscle consists of fibres which usually run its whole length, being thus 2 feet long in the sartorius; but they are occasionally interrupted by tendinous lines. They are packed together by areolar tissue, in which the nutrient vessels take a longitudinal course, and they become polygonal by mutual pressure. They are about $\frac{1}{400}$ in diameter. Each fibre can be split lengthwise into fibrillæ, or across into discs, which *Bowman* regards as the least artificial cleavage; but *Kölliker* says never occurred save in partly decomposed or digested muscle. *Prof. Hayden*, of the Catholic University, has arrived at the same conclusion, for he says, "The union into fibrils would appear to be the natural arrangement, and the formation of discs to result from the chemical re-agent employed." Each fibrilla is made of a number of square or slightly rounded cells arranged like a string of beads, the cross mark where they join giving the striated character which the fibre



Striped Muscle, teazed into fibrillæ at one end, cloven transversely at the other.

has. Each cell consists of a dark interior and light exterior, and is about $\frac{1}{3400}$ from stria to stria in man, in whom this measurement is greatest, and $\frac{1}{11000}$ in reptiles, in whom it is least, and about half as broad in the uncontracted state—these measurements being almost reversed during contraction. Each fibre is clothed by a fine, transparent, and hyaline sheath, which is best exhibited by breaking a fibre suddenly across, when it will hold the fragments still together. This is the myolemma; and as it is uncontractile, it can be seen under the microscope to rise into bulæ on the surface of a fibre when contracting. Each fibre ends abruptly in a tendinous thread which is continuous with the myolemma; and as it is much less bulky, a tendon of a muscle is very much narrower than the belly. Tendons achieve greater usefulness and symmetry, being cord-like if acting on one point, or diffused and membraneous if influencing the whole limb or its fasciæ.



The Capillaries of Muscle.

Muscle is chemically composed of syntonin, which differs from blood-fibrin in being soluble in hydrochloric acid. *Schultz* states that muscle-juice contains casein, as it is precipitated by rennet. The peculiar flavour of meat resides in the extract, not in the sarcous element, for the latter is tasteless in all animals, but may be made to acquire the taste of any kind of flesh by adding an extract of it. Inosite, the sugar of muscle, has been before described; it is found plentifully in unripe beans. As regards the nervous supply of muscles nothing can be said but that nerves are abundant, cross the fibres in loops, and have not been traced within the myolemma.

The supply of blood is most abundant, as it freely courses through the capillaries which lie parallel to the fibres. The red colour is due to the blood; and those muscles little used—as the pectorals constituting the breast of the fowl—are of a very pale hue.

The development of a fibre, *Schwann* shows, is accomplished by a number of cells arranging themselves in a linear form, and a granular matter is gradually laid down towards their centre. The growth of muscle to adult age, and the hypertrophy of it by exercise, is due to an increase in size, not in number, of each constituent cell. The contrary might be maintained from the slight difference in size between fœtal and adult fibres.

The trichina spiralis, a parasite discovered by *Wormald*, is peculiar to striped muscle; some distance below the constrictors of the pharynx it may be seen to suddenly stop. Many cases of disease, and some of death, have occurred from eating meat in which this parasite existed. (See my "Lectures on Public Health.") Another muscle parasite, the cysticercus cellulosus, has been shown to be the larva of the tænia solium, which it can readily give rise to, as the flesh of the pig in the condition termed "measly" abundantly contains it.

The striated tissue which we have now sketched forms all the voluntary muscles, and likewise those which, not being entirely under the control of the will, are denominated "mixed muscles," such as the diaphragm, heart, sphincters, pharynx, iris, tensor tympani, stapedius, &c. In most muscles the fibres lie parallel; in a few, as the accelerator urinæ and rectus femoris, they diverge, in a penniform manner and in parallel lines, from a central tendinous raphe. The more fixed end of a muscle is termed its "origin;" the more moveable, the "insertion." Their great variety, in shape, direction, position, attachments, and actions, gives rise to a most complex nomenclature. The following muscles are named from such particulars: triangularis oris, trapezius, rectus femoris, transversalis abdominis, glutei, intercostales, sterno-cleido-mastoideus, crico-thyroid, levatores costarum, extensor indicis, &c.

The Function of Muscles is contractility, which differs from elasticity in being a primary motive power. It is of two kinds—1. Passive, which is more usually termed " tonicity," and is that state of tension in which a muscle usually is. It continues during sleep and rest, and is seen clearly when, by a muscle being cut across, the bone on which it acted being fractured or its antagonist being paralysed, its ends approach each other. As *Prof. Hayden* has shown in the valuable paper to which I have before alluded, this passive contraction is usually nothing more than the elasticity of the muscle, especially of its myolemma, areolar tissue, and vessels. To such contraction the shortening in luxations of the limbs is due ; and in reducing them in powerful men, we have to seek the aid of that most efficient of the agents which relax muscles—chloroform. The constancy of the force shows its physical, not vital nature, as true contraction is only occasional, and is always followed by fatigue of the nerves supplying the muscle. The entire of a muscle does not act at once, but successive portions contract, while those that have previously acted are at rest. The stimuli to contraction are as follows: 1. The mysterious influence carried along the motor nerve, either originated by the will or reflected from some impression made on a sensitive nerve. This is often termed " vis nervosa." 2. Some molecular change, probably nutritive, which, since the time of *Haller*, has been regarded as inherent in muscular tissue, and named " vis insita." That there is such an inherent power in the tissue itself is suggested by a single fibril completely removed from the influence of nerves still contracting, and by experiments with the woorara poison. This substance, which has the power of destroying the conducting power of motor nerves, was placed under the skin of a frog, and when the nerve leading to the lower limb was rendered incapable of carrying the galvanic stimulus, the muscles still contracted by direct stimulation. 3. Such physical agents as heat, electricity, or mechanical contact, which probably excite the contraction of the muscles of organic life; thus, the contact of alimentary matter, or the distension produced by gases, are believed to excite the contraction of the muscles round the digestive tube. The sphincters at the orifices remain passively contracted without undergoing fatigue, till overcome by the more powerful efforts for expulsion of the contents. *Dr. Stokes* discovered an interesting example of contraction in a living voluntary muscle; if the pectoral of an emaciated patient, especially if phthisical, be struck smartly with the finger, some fibres will contract, and rise up into a prominent tumour.

Muscle during contraction becomes harder, but undergoes no change in bulk—merely altering in shape, gaining in breath what it loses in length. This can be shown by placing a muscle—the heart of an animal just dead being preferable, as it contracts by the mere stimulus of water—in a vessel of water, with a fine capillary tube leading from it; when the muscle contracts, no fall or rise of the water in the tube occurs. Fasciæ are of use in confining the bellies of muscles, and similarly, it is said, a well-fitting glove renders the hand stronger. At the precise moment of contraction it loses blood, by the capillaries between the fibres being pressed on; but increased afflux ensues.

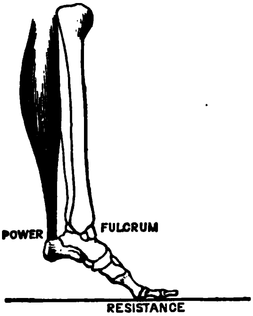
A peculiar sound, the "bruit musculaire," is produced, as mentioned when discussing the sounds of the heart. It is like the distant rumbling of carriage-wheels. *Wollaston's* expedient of placing the little finger in the ear, makes the noise very evident; and *Prof. Hayden* has proved that it is not due to the collision of the blood-cells in the vessels of the part, for it continued when all circulation was stopped in the finger by a tight ligature. When the limb was rested completely, so that no muscular action occurred, the sound ceased. It is probably due to the friction between the fibres as they successively contract; and to this friction and the increased flow of blood is also due the elevation of temperature, to the amount of two or three degrees, which always takes place in contracting muscles. So great is the shortening that a fibril is but ⅓ of its original length when fully contracted; but a muscle retains ⅔ of its length, as all its fibrils, or probably the entire of any of them, do not contract at once, and the tendons at its extremities are uncontractile.

Theories of Contraction are numerous, but the exact nature of the phenomenon is still uncertain. *Prevost* and *Dumas* suggested, as nerves cross fibres at right angles, that they caused them to assume a zig-zag form, and so become shortened; but it is found that it is the uncontracted fibres which put on this appearance when other fibres contract beside them. Any influence the nerves possess over the muscular fibres must be capable of diffusion along them, as they never lie parallel to the fibrillæ, but cross them in loops, and the nerve-tubes do not penetrate the sarcous element. Oxygen has been long believed to be the excitant to contraction, which is much dependent on a due supply of blood and nutritive change: thus, it is sudden and energetic in birds and mammals, to whom that gas is abundantly supplied; slow and lethargic in reptiles and hybernating animals, where the supply is scanty. *Marshall Hall* deduced the law, that "muscular irritability is in inverse ratio of respiration." *Draper* asserts that "muscular contraction is the necessary physical result of muscular disintegration;" and so rapidly do reparative changes occur, that the original condition is resumed after an inappreciable period. He refers to experiments, which show that chemical change always accompanies contraction, the alcoholic extractive of muscle being greatly increased by that act. Inosite, creatin, creatinin, and urea, are the products of muscular waste. It may be objected that the considerable shortening which a muscle undergoes could not be due to the amount of loss of material which one could suppose possible. *Draper* justly regards the experiment of placing muscle under water, to show that no change of bulk occurs during contraction, as most imperfect and inconclusive—as no calculation is made for the increased heat which would expand the water, or no provision for the removal of waste. The analogies of fibrillation and muscular contraction have been mentioned at page 122.

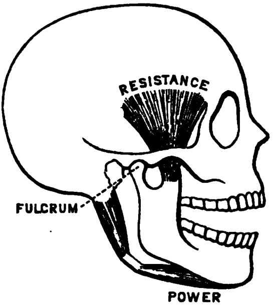
Rigor Mortis is the cadaveric contraction which occurs between somatic and molecular death. It is regarded by *Weber* as due to elasticity, which, he thinks, was prevented from coming into play by contractility during life. *Brücke* states that it is but the fibrillation of the muscle-fibrin, and thus identical with coagulation of the blood. Others regard it as the last vital manifestation, and after its departure all irritability is lost and putrefaction ensues. *Brown-Séquard*, by injecting defibrinated arterial blood, removed the rigidity from the limb of an executed criminal 4 hours after it had set in, and kept up the irritability of its muscle for 41 hours, until the opposite limb began to putrefy. By cutting off the supply of arterial blood, stiffness similar to rigor mortis may be produced in living animals. Rigor mortis usually commences about 4 hours after death, but has begun within 10 minutes, or has been delayed 7 hours. The earlier it begins and the more powerful it is, the shorter it lasts; whereas late and feeble contraction may endure for many days. It affects paralyzed muscles, unless much wasted. Involuntary muscles also exhibit it; thus the condition of the heart termed "concentric hypertrophy" is but a post mortem contraction, and the uterus has often expelled the fœtus by the same action, when the mother has died undelivered.

After death by lightning, sudden injury, typhus, glanders, and other septic poisons, and some other causes, it either occurs so soon and in so trifling a degree as not to be perceived, or does not take place at all. It usually begins in the jaw and neck, and proceeds to the upper and lower extremities, from above downwards, departing in the same order.

The muscular force of the human body is utilized and increased by the frequent adoption of the lever. There are three kinds of this mechanical power—1st, where the fulcrum is intermediate, and the power and resistance at the ends. Of this kind there are not many examples. We have here represented one which is often incorrectly described as of the second order. In rising on tip-toe, the ankle is the fulcrum, the gastrocnemius the power, and the ground the resistance. Other examples are afforded when we erect ourselves after the trunk is bent forwards, the hip being the fulcrum, the hamstrings the power, the weight of the body the resistance; and in the nodding of the head backwards and forwards at the occipito-atlantoid joint. The 2nd order is best exemplified in the act of opening the mouth by the action of the digastric, which is the power, the tem-

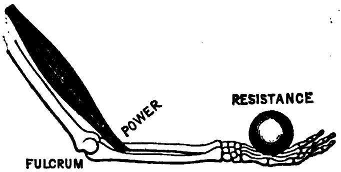


1st Order.—Rising on Tiptoe.



2nd Order.—Opening the mouth.

poro-maxillary articulation being the fulcrum, and the resistance the temporal, which is intermediate. The 3rd order is by far the most frequently used. We have selected the well-known example of the biceps, which is the power intermediate, the elbow being the fulcrum, and the hand, with any body grasped in it, the resistance. The deltoid, brachialis anticus, rectus femoris, temporal, and many other muscles, act with the aid of this kind of lever, as the greatest velocity is thus acquired, although with some loss of power. *Sir C. Bell*, in his charming book on "The Hand," says: "The same interchange of power for velocity which takes place in the arm, adapts a man's hand and fingers to a thousand acts requiring quick or lively motions. The fingers of a lady at the pianoforte, or of a compositor with his types, are instances of the advantages gained by this sacrifice of force for velocity of movements."



3rd Order.—Flexing the Forearm.

The power is usually placed very near the fulcrum, so that in the case we have sketched, if the biceps contracts one inch, the hand will traverse the space of a foot, but through each inch with only $\frac{1}{12}$ of the muscular force—a power which would bring all to rest if exerted in opposition.

The following attitudes and motions afford examples of associated muscular actions.

Standing in the erect posture is, as we have before stated, an attitude peculiar to man. The weight of the body is transmitted through many joints, and a line dropped through the centre of gravity must fall within the base of support—an invariable law of stability. In some instances the attitude is preserved more easily by rapidly changing the centre of gravity—thus, the drunken man is less liable to fall if he runs than if he tries to walk slowly.

Walking is performed by flexing the knee and extending the ankle of one leg, which is thus raised from the ground; the weight is then thrown and the body inclined towards the opposite limb, which, by acting on the ball of the big toe, rises it from the ground, and transfers it to the limb which was first moved.

Running is accomplished by similar, but more rapid movements, the body being also constantly bent forwards. In leaping, both legs are raised at once from the ground.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. What varieties of motion are presented in plants and animals?
2. Describe the structure, distribution, and uses of white fibrous tissue, and the points in which it differs from the yellow.
3. Sketch the histology of the articular and membraniform varieties of cartilages.
4. Describe the arrangement of the bones in the most movable and the most immovable kinds of articulation.
5. Enumerate the notions of the older writers on the structure of bone, and describe what you have seen under the microscope.
6. What are the uses of bones, and why are the long ones hollow?
7. Explain how bones grow.
8. Describe the phenomena of muscular contraction and of the rigidity which occurs post mortem.
9. What are the orders of levers? Give an example of each.

SENIOR.

1. Describe ciliary motion, stating in what particulars it agrees with and differs from muscular contractility.
2. What synonymes have been applied to areolar tissue? With what other tissue is it associated, and in what situations do their respective amounts vary?
3. Give a precis of *Prof. Redfern's* researches on abnormal nutrition of cartilages.
4. What are the components of bone, and how may each be demonstrated?

5. Do the relative proportions of salts and gelatin vary with age, or with the hardness of bone?
6. From what other microscopic object could you predict the size of the lacunæ of any animal?
7. Mention a few of the proportions which exist between the weights of the bones of animals.
8. Sketch the minute anatomy of voluntary muscle, and contrast its structure and properties with those of the two other varieties.
9. What are the stimuli to contraction, and which of them has influence longest after death?

VOICE AND SPEECH.

In man, voice is more perfect than in any other animal; and speech, expressing thoughts and feelings, is his special prerogative.

The Larynx is shown to be the organ of voice by that faculty being lost if the air be allowed to escape before passing through it, as we see in persons on whom we have performed tracheotomy; by the aphonia which results from injury of the vocal cords or inferior laryngeal nerves; and also by sounds being produced by blowing through the larynx, removed after death. The organ is made up of the following structures: 4 true cartilages—thyroid, cricoid, and 2 arytenoid; and 7 false or fibro-cartilages—the epiglottis, 2 cuneiform, 2 cornicula, and 2 corpora triticea, which are jointed by many ligaments, the elasticity of which increases the vocal vibrations, and moved by several muscles we shall afterwards allude to. In a physiological point of view the two openings of the larynx, the glottis and the rima glottidis, are the most important. The former lies behind the epiglottis, and between two mucous folds which pass from it backwards and inwards to the arytenoid cartilages; it is widely opened during inspiration, and during deglutition is shielded by the epiglottis, which, falling backwards and downwards, closes it like the lid of a box.

The vocal cords, or thyro-arytenoid ligaments, are 4 in number—2 at each side. The false, or superior, are wide and loose, and are divided from the true, or inferior, by a space termed the ventricle, from which a small cavity leads off, the sacculus laryngis of *Hilton*, of use in secreting mucus to lubricate the cords. Each true cord arises from the concavity of the thyroid cartilage, and is inserted into the anterior angle of the base of arytenoid cartilage; the thyro-arytenoid muscle lies along its outer edge, and adheres to it. It is composed of yellow elastic tissue, and measures about $\frac{9}{10}$ of an inch, or somewhat less in the female. Voice is due to their vibration, excited by the air as it is expired, a fact first stated in 1741 by *Ferrein*. The cords converge in front, and leave a triangular space between them, the rima. When the organ is quiescent, their surfaces are not parallel to the column of air, but during vocalisation they become so, as demonstrated by the *Rev. Prof. Willis*, of Cambridge—owing, as he believed, to the action of the thyro-arytenoid muscles. *Prof. Croker King*, late of Queen's College, Galway, has proved, by experiment and most ingenious arguments, that this parallelism is mainly effected by the oblique fibres of the arytenoid muscle, which constitute part of a bent lever of the first order. He describes, as follows, the effect on the vocal cords of the motions of the arytenoid cartilages: "The forward motion will relax and the backward movement will stretch the vocal cords; the rotation in a direction outwards on the vertical axes will separate, and the rotation inwards will approximate the vocal cords; the rotation on the horizontal axes, inwards and outwards, will cause the anterior spur to revolve, and to carry with it the vocal cord, which will thus alternately incline towards and from the cord of the opposite side." His valuable paper will be found in the "Transactions of the Royal Irish Academy for 1849." The cords are but from $\frac{1}{10}$ to $\frac{1}{12}$ of an inch asunder when vocalising. Areolar tissue seems to be absent between the mucous and elastic layers of the cords, as I have seen illustrated in cases of laryngitis, for the œdema does not extend below them. Such lax tissue would probably interfere with their vibration.

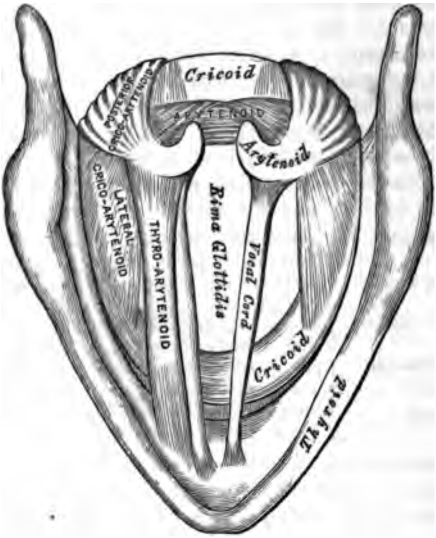
The muscles of the larynx and their actions are thus tabulated by *Todd* and *Bowman:*

Crico-thyroidei	stretch the vocal cords		govern pitch of notes
Thyro-arytenoidei	relax and place the vocal cords in the position for vocalisation		
Crico-arytenoidei postici	separate the front of the arytenoid cartilages	open glottis	govern aperture of glottis
Crico-arytenoidei laterales	press together the front of the arytenoid cartilages	close glottis	
Arytenoidei	press together the back of the arytenoid cartilages		

The muscles, cartilages, and cords concerned in vocalisation, are represented in the bird's-eye view of the organ on the following page, and their relative position should be carefully studied in order to comprehend the exquisite mechanism of the organ.

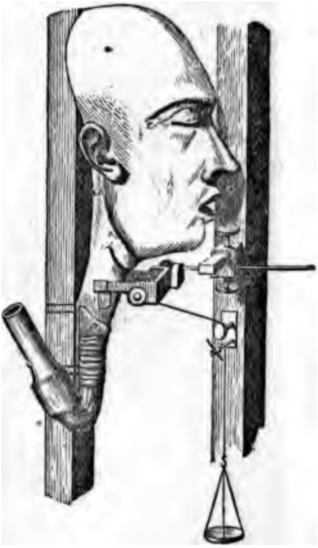
The larynx is supplied by 2 branches of the pneumogastric—the superior sensitive, which serves to test the air; and the inferior, or recurrent laryngeal, which supplies all the muscles save the crico-thyroid, to which the spinal accessory sends a branch, accompanying the superior laryngeal. Section of the inferior will prove fatal by paralysing all the muscles, and the falling together of the arytenoid cartilage and cords produces apnœa. The larynx has been compared to every variety of musical instrument—the stringed, as the violin; the wind, as the trombone; but to those which produce sound by the vibration of a tongue—as the hautboy, accordeon,

&c.—it bears most resemblance. When the cords are tense they vibrate rapidly, and a high note is produced; when relaxed, fewer vibrations, and a lower sound. A string, made tense by a given force, will vibrate twice as rapidly if the force be multiplied 4 times; but in the larynx there are so many modifying circumstances, these results do not exactly hold good. *Willis* constructed an artificial larynx, in which strings of caoutchouc represented the vocal cords; and, with the head of a subject arranged as here sketched, many vocal sounds can be imitated, and the effect of tension or relaxation, approximation or separation of the cords determined. The laryngoscope, so much improved by *Prof. Czermak*, will assuredly improve our knowledge of the physiology, as it



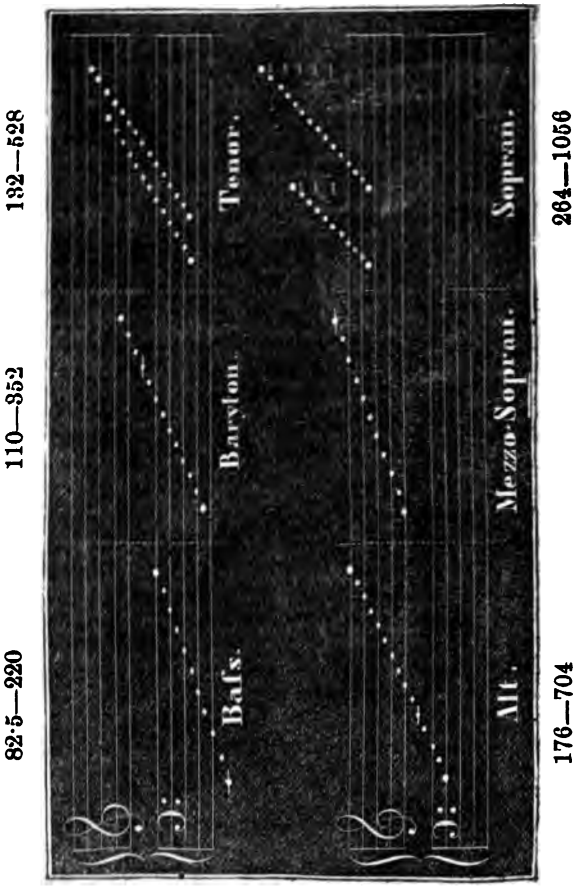
The Larynx viewed from above.

has the pathology of the organ of voice. When that physiologist visited Dublin, the effect of an aortic aneurism, in paralysing one side of the organ by pressure on the left recurrent nerve, was readily seen in a patient of mine.



Head and Trachea of a subject, with weights attached to produce degrees of tension of the vocal cords.

The pitch of the human voice varies with the length, tension, and elasticity of the cords, and with the expiratory power of the chest. In singing, the vibrations succeed each other with exactly uniform rapidity. The following scale shows the range of the male voice (bass, barytone, and tenor), and that of females, males before puberty, and eunuchs (alto, mezzo-soprano, and soprano). The number of double vibrations per second which take place during the exercise of each kind of voice is noted. The concert pitch of the principal London orchestras has been shown by *Mr. Donovan* to be nearly 450. The compass of the human voice extends from 1 octave to 3½, which Catalani is said to have possessed. About 300 notes can be produced between the successive tones, a power peculiar to the human voice. Falsetto notes are produced by the inner edges or anterior half of the cords alone vibrating. So great is the variety of voice that the old and young, male and female, and different individuals, may be distinguished by a peculiar tone; and the vocal cords and



The Register of the Voice.

other parts of the larynx must present minute differences, as difficult, however, to characterise as those which the human countenance presents.

SPEECH

Is performed in the buccal cavity, and that the larynx is unconnected with the faculty may be proved by passing a tube through the nares to the back of the mouth; when air is forced through it while the breath is held, articulate sounds are expressed, but in whispers. If the larynx was used at the same time, vocal sounds were emitted along with the whispers. The proportional dimensions of the oral aperture and buccal cavity give rise, in a great measure, to the different vowel sounds, as shown by the following table:

			Size of Oral Aperture.	Size of Buccal Cavity.
a	as in	ma	5	5
a	,,	name	4	2
e	,,	theme	3	1
o	,,	cold	2	4
oo	,,	cool	1	5

The diphthongs are produced by the transition of these states in producing two pure vowel sounds.

Consonants are divided into explosive or sudden, including **b**, **p**, **d**, **t**, **g**, **k**, and continuous, namely, **v**, **f**, **l**, **m**, **n**, **r**, **s**, **z**, and also the sounds **th** and **sh**, which, though written in many languages with two letters, are really simple sounds. The division into labial, dental, lingual, palatal, and guttural, is inaccurate and artificial.

Speaking Machines have been often attempted. It is said one constructed by *Kempelen* could pronounce such sentences as "Je vous aime de tout mon cœur," "Imperator Romanorum," &c.

Ventriloquism was said by *Magendie* to be but the imitation in the larynx of sounds produced at a distance;

by others, to be produced by using the air in inspiration instead of expiration, for vocalising; and by *Müller* to be performed by filling the chest so fully as to protrude the abdominal viscera, and then allowing air to escape slowly by contracting the sides only of the chest, the glottis also being kept narrow. An expert professor of the art also deceives our other senses by directing attention to some spot in the direction whence we suppose the sound to issue.

Stammering is usually no structural fault of the vocal organs, but a nervous affection—volition, and co-ordinating influence over the articulating muscles being imperfect. It is, therefore, much augmented by mental excitement and the anxiety to speak correctly which is usually evinced, and these facts suggest to us the principal curative indications.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. What constitutes the skeleton of the larynx, and what the active parts?
2. What is the action of the posterior crico-aryteniod muscles?
3. What musical instrument resembles the larynx most, and explain the analogies?
4. Can the nature of ventriloquism be explained physiologically?

SENIOR.

1. Explain the mechanism of the vocal cords, and say how they are stretched, relaxed, approximated, and separated.
2. Arrange the varieties of voice according to the rapidity of vibrations.
3. What are the organs of speech, and how has it been shown that articulation is not produced in the larynx?
4. What are the nature and remedy of stammering?

CRANIAL NERVES AND SPECIAL SENSES.

THE cranial nerves are 9 in number according to *Willis's* arrangement; whereas *Sömmering*, by subdividing the 7th and 8th, enumerated 12. Their functions are most varied, some being specially sensitive, others purely motor, and a third class are compound. As all of them, except the pneumogastric and spinal accessory, are in part or wholly distributed to the organs of sense, it will be best to consider them in describing these organs. They may, however, be classified according to their functions as follows:

Special.	**Motor.**	**Mixed.**
1st. Olfactory.	3rd. Oculomotor.	5th. Trifacial.
2nd. Optic.	4th. Trochleator.	8th Pneumogastric.
(5th. Gustatory of trifacial)	6th. Abducens.	
7th. Auditory.	7th. Facial.	
8th. Glossal branch of glosso-pharyngeal.	8th. Accessory.	
	9th. Lingual.	

The special senses, "the gateways of knowledge," are five in number—namely, touch, taste, smell, sight, and hearing; and they are termed special, as each has its proper excitant to which the others are insensible. The three first require the application of ponderable agencies; light and sound are imponderable influences. Sensations are objective when an impression is made on the periphery, and conducted back by the nerve to that part of the cranio-spinal axis appropriated for its perception; subjective, when produced by some central cause.

TOUCH

We shall first describe, as it is the most generally diffused over the body, and also throughout the animal kingdom. It exists in the interior of the body, and we become thus aware of such conditions as pain, warmth, repletion, &c.; but as it attains the highest degree of perfection on the surface, we may regard the skin as its special organ. The annexed diagram represents a section of the skin, and its various parts are described in the ensuing pages.—On the surface is seen the cuticle, with the deeper cells more rounded and of a darker colour than those which lie externally, the gradual transition showing that the rete mucosum, or layer between the cuticle and cutis, has no real existence. Next are seen several papillæ with branching nerve filaments, and at the base they are seen to be continuous with the basement layer. The areolæ of this portion are filled with fat cells. To the left is seen a perspiratory gland and its excretory duct taking a spiral course through the cuticle. A hair is figured in its follicle, into which is inserted one of the erectores pilorum, and two sebaceous glands, with an entozoon in each.

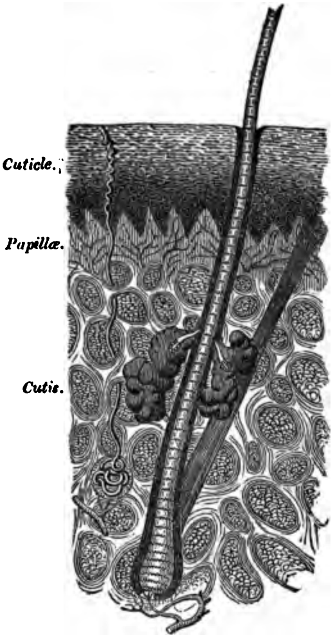


Diagram of the Skin.

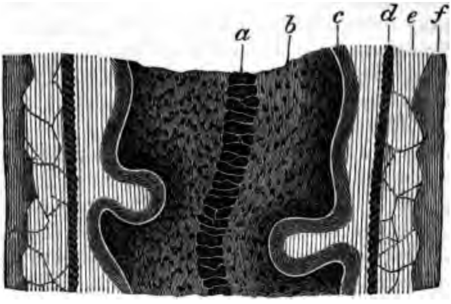
To the left is a perspiratory tube, and in the centre a hair in its follicle, with an erector muscle attached, and two sebaceous glands opening into it.

The skin, like the internal integument we have before described, is divisible into 2 layers—the cuticle and cutis vera.

The Cuticle, epidermis, or scarf-skin, is thickest in places exposed to pressure—as the soles of feet and palms of hands—and as it follows the arrangement of the true skin, it presents furrows and other markings, in some situations, as the fingers. It is composed of cells—round, large, and moist next the cutis, and getting flatter, smaller, and drier, through successive layers, till, becoming scales, they are cast off at the surface. The deepest and newly-formed cells constitute the "rete mucosum, vel Malpighii." They are of a darker colour, being filled with pigment granules, and are black in the Negro. Scars are white, as the new cuticle and cutis adhere, the rete mucosum not being restored. The coloration due to nitrate of silver and bile has its seat in this tissue. The dark colour of races inhabiting warm countries is of use in absorbing the rays of heat, producing evaporation and consequently cold. It appears to be due originally to the carbon of the tissues not being sufficiently burned off, as the air is so rare in the warm countries which they inhabit and their diet is so carbonaceous. The sweat ducts open obliquely through the cuticle—so that when serum collects under it after a blister, it does not escape.

Cuticle, as well as hair and nails, consists of keratin, a substance intermediate between the albuminoids and gelatin, and containing sulphur. The cuticular appendages are the nails and hairs. Nails and their analogues—claws and hoofs—serve for prehension or support at the extremities of the fingers and toes. The root of the nail is set upon a highly vascular and sensitive surface, the matrix, consisting of a row of papillæ, which secrete the horny tissue, and which, for this reason, often presents longitudinal streaks. Near the root there is a whitish, opaque, semilunar mark—the lunula—and in front of this, streaks corresponding to the markings of the cutis. Nails grow rapidly and in a peculiar curved or adunque form in phthisis.

Hairs grow on all parts of the skin save the palms and soles, and more abundant on the ventral than the dorsal surface in man alone. A hair consists of a bulb lodged in a follicle, and a shaft projecting beyond the skin. The follicle is an inflection of the cuticle, and its cells become continued on the hair, being loaded with pigment if its hue is dark. The shaft consists of a soft pith, or medulla, and a cortex which forms $\frac{1}{4}$ of the entire thickness, and is composed of horny scales, inbricating or overlapping each other in a manner peculiar to each animal. The latter fact has been taken advantage of in medico-legal investigations to distinguish human hair from that of other animals. Its diameter varies from $\frac{1}{140}$ to $\frac{1}{1500}$, black hair and that of the beard being coarser than flaxen hair or that of the head. When they are cut short they again become pointed at the end, which is said to prove organization. Feathers, down,



Section of a Dark Hair, after Kölliker.
a. Medulla. b. Cortex with pigment spots. c. Inner layer of epidermis. d. Outer layer. e. Inner root-sheath, or Huxley's layer. f. Outer, or Henle's layer.

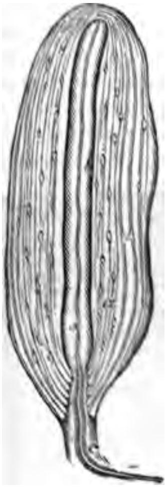
quills, and even horns, are modifications of this cuticular appendage. The medulla is soft, and apparently tubular in some animals; and in the seal, cat, &c., a nervous and vascular papilla is developed at the root. In other animals the erectores pilorum, or muscular slips which produce the state called cutis anserina in man, are very distinct. The colours of hair—black, brown, red, or yellow—depend on the quantity of iron in the pigment, which is of an oily nature. It has been said that fright or other emotions have decolorized hair in a few hours, but as no vessels permeate it, these statements are unaccountable. Hairs when rubbed become electrical, and are so sensitive to atmospheric changes as to be used as hygrometers. In the remarkable disease termed "Plica Polonica," hairs become matted together by a glutinous secretion, and are said to bleed when cut. It is said hairs grow after death, which opinion has originated from the projection of them, owing to the shrinking of the skin and tissues beneath it.

The Cutis is composed of white and yellow fibres, the former abounding where fixity is necessary, as in the sole of the foot; the latter predominating wherever elasticity is required, as near joints. Acetic acid dissolves the white, and thus displays the yellow arranged in diamond-shaped meshes; and tannin converts it into an insoluble matter, as in the making of leather.

Capillaries of the Skin.

The contractility of the skin after death, if stimulated by galvanism, indicates the presence of muscular tissue, and this is most abundant in the scrotum and about the nipple. The cutis lies on a layer of areolar tissue, the superficial fascia. Lymphatics are so abundant in some places that their meshes are but $\frac{1}{200}$ wide; medicines applied endermically by blistering or inunction are thus readily absorbed. The surface of the cutis is covered with nervous and vascular processes about $\frac{1}{100}$

in length, the papillæ, and this layer is termed the corpus papillare. Their size and number vary in different parts of the body; in the hand they are arranged in curved rows to which the cuticle corresponds, there being often 40 rows in one square inch, and 60 pairs of papillæ in each row. A little artery enters each papilla, and is united to a vein by capillaries in loops. Nerve-tubes can be traced as far as the papillæ, in which they become indistinct—probably, by losing the white substance of *Schwann*, as in other special sense expansions. *Wagner* discovered "corpuscula tactus" in them, which are analogous probably to the *Pacinian* corpuscles.



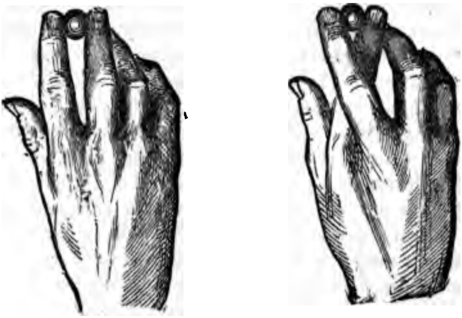
A Pacinian Corpuscle, with the nerve-axis in the centre.

These latter bodies are found in the nervous pulp of the fingers and toes, especially if roughly used, and also in the mesentery of the cat, and other places where tactile sense does not seem to specially reside. As they measure $\frac{1}{15}$ they can be seen readily on the twigs of the digital nerves. A nerve-tube passes up through the whole axis of the body, and having lost its white substance, is of a pale colour. It usually ends in a blunt extremity, but in some instances it passes on to another corpuscle on the same nerve-stalk, and then regains its outer coat as it leaves the first corpuscle. The rest of the body consists of concentric laminæ, often 60 in number, the outer being separated by fluid which escapes as each layer is punctured. From this arrangement their discoverer compared them to the electric organs of some fishes. That they are rather ganglionic than essentially appendages to the spinal system, would appear from the fact that they are enlarged in paralysed limbs, and *Cruveilhier* regards them as altogether abnormal.

The Glands of Skin are, 1, sebaceous, which always accompany hairs, and are therefore absent in the palms and soles. They are largest and most numerous about the nose, arms, groin, and other flexures. They lie under or in the structure of the cutis, and 2 or 3 open into each hair follicle. They secrete an oily hydrocarbon, of which the system is thus ridded, and which serves to lubricate and render pliant the skin. *Simon* discovered the entozoon folliculorum in these glands. The Meibomian glands and the odoriferous glands, which *Tyson* discovered round the glans penis, are modified sebaceous glands. The latter are peculiar in not accompanying hairs; the smegma præputii which they produce contains many epithelial scales. The wax glands of the ear pour out a material somewhat analogous to sebaceous secretion, but in anatomical configuration they more resemble the sweat glands. 2. The sudoriferous glands lie deeper, usually set in the subcutaneous fat, the particles of which they much resemble—but they have a pinker tint. Each consists of a tube inflected from the cuticle which gives it its epithelial lining, the basement layer being derived from the true skin. It is spiral in the cutis except near the papillæ, and again spiral while it passes through the cuticle; and as it has no basement layer here, it may be regarded as merely a tubular passage in it. It opens in an oblique or valve-like orifice about $\frac{1}{1600}$ in diameter. *E. Wilson* calculates there are 3528 perspiratory openings on the square inch of the palm, or 2800 on an average over the whole body. As the surface of a man of ordinary stature equals about 2500 square inches, and as each duct is about ¼ of an inch long, he concludes there are 28 miles of such tubing altogether.

The functions of the complex organ we have sketched are numerous, and may be divided into mechanical, sensitive, and excretory. 1. The skin affords a tough yet flexible and elastic covering to the whole surface—modified in various places according to circumstances. The cuticle, like a varnish, retains moisture, and when it is removed from any part of the subject, this soon dries up; it also blunts the too high sensibility of the papillary surface. Its appendage, hair, tends to preserve a uniform temperature. The skin is not impermeable to moisture, as increase of weight takes place by immersion in a bath, and thirst has been thus relieved. It is probable that the hands and feet are the only place where absorption of water takes place, as all other parts are made water-proof by the sebaceous secretion. 2. The relative sensibility of different parts of the surface depends chiefly on the number of papillæ, and can be determined by *Weber's* method. He placed the points of a compass, slightly blunted, at various distances on the skin of a person blindfolded, and found, for instance, that they should be separated 3 inches on the back of the thigh before they were perceived as separate points of contact. On the tip of the tongue and the middle finger a separation of $\frac{1}{36}$ gave rise to two perceptions of touch. These results did not vary in one individual for 11 years. The difference depends much on the thickness of the cuticle, for there are not 50 times as many papillæ upon the tongue as upon the back. This method may be employed to ascertain the amount of anæsthesia in many cases of disease. If the points be drawn from a sensitive surface to one less so, the person will think they converge, and *vice versa*. The other senses greatly aid touch, and if they are lost it becomes greatly exalted—thus, our noble countryman, *Lord Rosse*, informs us that the only efficient polisher of telescope specula in London, some years ago, was a blind man named Cuthbert. Saunderson, professor of mathematics at Cambridge, although blind, could distinguish spurious medals from genuine ones by touch, and *Rudolphi* records an instance where a blind man could distinguish different coloured cloths. These remarkable results were probably due to different conducting powers, for if rods of metals be immersed in a water bath, they will also assume a slightly varying temperature. Glass and delph only feel cold for a short time, till the surface becomes heated; but metal, which is a better conductor of heat, feels cold much longer. We can obtain much information by the amount of pressure we make on the surface—thus, if we take another person's finger, and move it over a plane surface, first lightly, and then with greater pressure, and then lightly again, they will believe the surface is convex, or concave if this order be reversed.

Another remarkable deceptive sensation is noticed by *Aristotle*. If a pea be rolled between the index and middle finger, we do not get a separate impression from each finger; but if they be crossed, as here sketched, the judgment completes each impression, which do not correspond, into a separate object.



Aristotle's Experiment with a Pea.

The weight of bodies, too, we often judge of from previous conception. Thus, shortly after *Sir H. Davy* had discovered the metal potassium, he placed some of it in the Rev. Dr. Pearson's hands, who exclaimed: "Bless me! how heavy it is!" although its specific gravity is less than that of water. We estimate the weight of bodies partly by touch, and partly by the amount of muscular exertion necessary to support them. To such a property the term "muscular sense" is given by many. *Schiff*, however, states that we gain information as to the state of our muscles by the folding and stretching of our skin, an idea which *Lewes* endeavoured to controvert by showing that a skinned frog could perform purposive movements.

The sensations of heat and cold are probably conducted by the ordinary nerves; but there are some cases recorded where these feelings were lost though common sensation remained. Besides the degree of temperature, the extent of surface, the amount of heat, and period of application of a heated body make much difference; thus, the whole hand cannot bear hot water, which the finger can without inconvenience. If one hand be placed in hot water and the other in cold for some time, and then if both are plunged in water of a medium temperature, this will seem cold to the hand which was in the hot water, and hot to that which was in the cold. This observation, and the well-known fact that a moderate climate will differently affect the inhabitant of a hot or cold climate, shows that such sensations are merely relative; but the skin gives us useful warning of changes of temperature, so necessary in our variable climate. The right hand, which is more sensitive to ordinary impressions than the left, is less so to that of temperature. As is the case in other senses, sensations may remain long after the impression is removed. Subjective sensations are examplified in such feelings as tingling—those known as "pins and needles," being "asleep," creeping of insects (formication), itching, chilliness, and a great variety of pains, all referable to central causes.

3. As regards cutaneous secretion, the great quantity of epidermis which is constantly being shed may be regarded in that light, and the sebaceous matter is also a hydro-carbonaceous effete product. We have seen be-

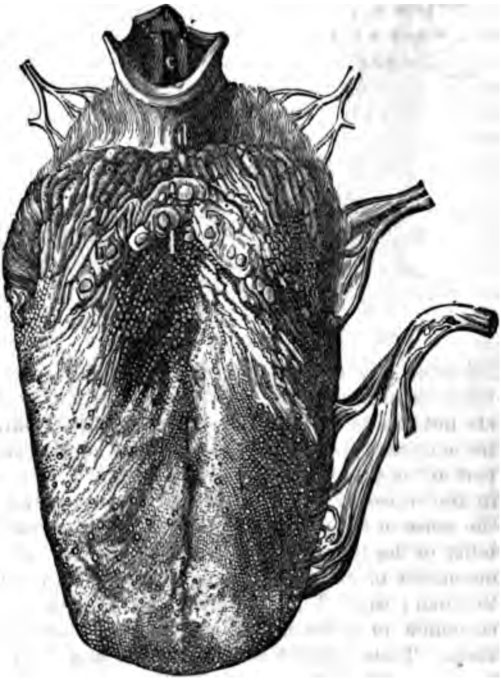
fore that the skin was a respiratory surface, producing that characteristic result of combustion—carbonic acid; and, lastly, this organ rids the blood of superabundant water and some saline materials. The great system of sudoriferous glands differs from most others in not being aggregated into one mass, but spread over a great extent, and it is thus more exposed to atmospheric changes, according to which its activity is regulated. Sensible and insensible are the names given to perspiration, according to its amount; and the latter, which is a constant secretion, was determined by *Lavoisier* and *Seguin*, by enclosing the body in a water-proof bag. They found the quantity equal to 11 grains per minute, or about 2¾ ℔s. daily, and the amount of pulmonary exhalation was 7 grains in the same period. *Valentin* calculated the entire daily excretion by skin and lungs at 3½ ℔s., which was precisely the amount *Southwood Smith* found men employed in gas works lost in one hour. The secretion from the skin contains:

Water..............................	995·00
Animal matters with lime..........	0·10
Sulphates and matters soluble in water............................	1·05
Chlorides...........................	2·40
Acetic acid, acetates, lactates, and alcohol extracts	1·45
	1000·00

Lactic acid, muriate of ammonia, oxide of iron, fatty matter, urea, and, very plentifully, formic acid, are some other constituents which chemists have detected. This latter acid, so named from being first found in the formica or ant, constitutes the stinging poison of some insects. *Rev. Prof. Haughton* has however never been able to detect any nitrogenous matter excreted from the skin. The nicely-balanced relation between the activity of the kidney and skin has been alluded to when describing the functions of the former. About 100 grains of solid matter is excreted daily by the skin; but this is hardly enough to produce the debility which often accompanies profuse sweating; colliquative perspiration is more a result than a cause of weakness, and the fatigue produced by exercise in a heated room is rather the effect of want of air. The organic matter is in a decomposing state; and thus, if retained in the system, owing to an obstructed state of the cutaneous glands—or if inspired, owing to defective ventilation, becomes a prolific source of zymotic diseases. I have dwelt at length on means we possess for preserving cutaneous functions in my "Lectures on Public Health."

TASTE

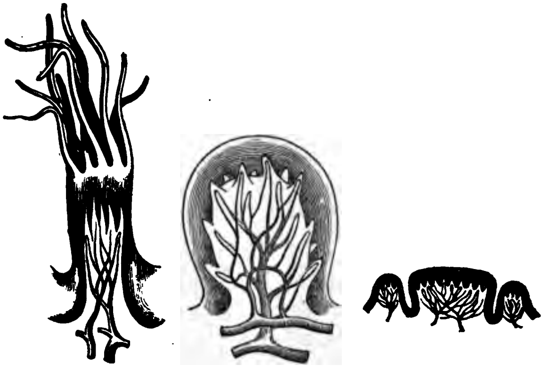
Is exercised principally by the tongue—an organ composed of many muscles woven together, only one of which, the lingualis, is intrinsic to it. Its exquisite mobility fits it for the purposes of mastication, deglutition, and speech, as we have before described, but it still remains to be considered as the organ of taste. The mucous membrane of the upper surface of the tongue has a thick scaly epithelium, which, when thrown off too abundantly, forms the fur characteristic of many diseases. The papillæ are of 3 kinds. 1. Filiform, which occur chiefly along the centre, where they are curved backwards. Their epithelium forms stiff brush-like projections about a line long. These papillæ are more connected with mastication, as they can rasp and bruise the food, and with them the tiger can remove the skin from the animal on which it preys. They can likewise estimate the muscular effort of mastication. 2. Fungiform, which are found along the tip and sides of the organ, mingled with the last described. They have many secondary papillæ on their surface, and having thin cuticle they rise up as little red points if any acid or other sapid body is placed on the tongue. 3. The calyciform papillæ are surrounded by a furrow—hence termed circumvallate—and lie at the base of the tongue arranged in two rows of 5 or 6 each, converging behind to the foramen cœcum, which is just in front of the epiglottis with the uvula dangling just over it.



The Tongue: its papillæ, glosso-pharyngeal, gustatory, and lingual nerves.

All the papillæ are freely supplied with blood by an artery which loops within them, and the nerve-tubes are said to have the same form of distribution, but their exact mode of termination cannot be determined; they have been said to be traced as far as the epithelium.

All sapid bodies are soluble, but the physical qualities of insoluble bodies can be also ascertained by the tongue, which we mentioned has exquisite tactile sensibility.—



The Filiform, Fungiform, and Calyciform Papillæ.

All sapid substances belong to the class of bodies which *Graham* terms "crystalloid," for the "colloid" substances are not able to diffuse through the membrane which coats the surface of the papillæ. The palate, cheeks, and upper part of the pharynx have slight gustatory power—so that in *Blumenbach's* case of congenital absence of the tongue, the sense of taste was still present. The exquisite sensibility of the sense of taste may be judged by the minute quantities of various sapid substances which it can distinguish; thus, I have found that $\frac{1}{1000}$ of a grain of strychnia in a drachm of water gives a distinct bitter taste. Taste is much aided by smell, and the two functions are usually exercised together; either pleasant or nauseous flavours are much decreased by holding the nose so as to prevent the odour of the body which is being tasted from passing through the nares. Pressure and prolonged application of the sapid body favour taste, and some substances leave a most persistent impression on the organ.

A certain taste is occasionally followed by the subjective sensation of an utterly different one; thus, many sweets give rise to a bitter after-taste, and tannin, which is intensely bitter at first, tastes somewhat sweet after a while. It depends on exhaustion of the nerve to one stimulus, and is analogous to the phenomena of complementary colours. After frequent use, the papillæ seem to lose their gustatory power, for if the tongue be protruded and salt and sugar applied alternately, we cannot after a while distinguish between them until the tongue is applied to the palate. If the tongue be kept in water either at 125° or 32° for a minute, it loses all gustatory or tactile endowments. The relative gustatory power of various parts of the tongue may be ascertained by applying sapid bodies in capillary tubes, or by covering it with a glove of softened parchment, with apertures where we wish to make the experiment. Electric currents, a smart tap, or a stream of air, produce gustatory impressions on the tongue. As an instance of subjective sensation of taste, *Magendie* states that dogs licked their lips and seemed to taste when he injected milk into their veins; but some of that fluid may have been conveyed to the lingual papillæ, and have thus produced a real objective effect. In the same way the bitter taste often existing in the mouth during indigestion may be due to biliary matter being brought to the organ of taste. The trifacial, glosso-pharyngeal, and lingual nerves may be here conveniently considered, as these cranial nerves endow the tongue with its peculiar functions.

The Trifacial, usually numbered the 5th nerve, is remarkably analogous, as *Sir C. Bell* noticed, to the spinal nerves in having a sensitive and ganglionic root, which a motor twig then joins. The inferior maxillary branch is compound, in the sense of having a motor and sensitive portion, but it gives off separate motor and sensitive twigs, and none of which are really mixed in function. The nerve seems to arise from the side of the pons, but

Prof. Alcock, late of Queen's College, Cork, traced it to the groove on the floor of the 4th ventricle.

The sensitive root forms the Casserian ganglion, and then divides into 3 portions, the distribution of which is as follows:—

I. OPHTHALMIC

1. Frontal
    - Supra-trochleator, to skin of eyelids, canthus, &c.
    - Supra-orbital, to skin of forehead.
2. Lacrymal
    - To lacrymal gland.
    - To conjunctiva.
    - To join the facial nerve through malar bone.
3. Nasal
    - A root to the lenticular ganglion.
    - The ciliary nerves.
    - The infra-trochleator, to inner canthus and side of nose.
    - The proper nasal

II. SUPERIOR MAXILLARY—

1. Temporo-malar, joining lacrymal, supplies malar and temporal regions.
2. Spheno-palatine, to *Meckel's* ganglion.
3. Posterior superior dental.
4. Infra-orbital, to the skin of the face.

III. INFERIOR MAXILLARY—

1. Inferior dental, which sends the mental branch to the skin of the face.
2. Gustatory, to lingual papillæ.
3. Temporo-auricular, to the skin of ear and temple.

The branches from the motor division are:

4 & 5. Temporal

6. Masseteric.

7. Buccal.

8. Pterygoid.

9 & 10. Mylohyoid and digastric, which accompany the inferior dental.

The functions of this great nerve may be ascertained in 3 ways—1. Its distribution. All these nerves are sent to sensitive surfaces, except the last six, which supply and associate the muscles of mastication. Two of these muscles, the buccinator and digastric, also are concerned in respiration, and thus receive a second supply from the facial nerve.

2. By experiment. Irritation of the motor root causes spasm and division of it, paralysis of all the masticating muscles. Very remarkable effects follow the section of the sensitive root. One side of the face is rendered quite insensible, and irritants may be applied to the conjunctiva, nasal surface, or mouth without any effect. The conjunctiva becomes dry, the cornea grows dull, then quite opaque, and at last sloughs, and the entire eye is destroyed. These effects are partly due to the lodgment of dust which excites destructive inflammation, and in a greater degree to the impairment of nutrition. Many believe that it is the injury to the sympathetic, necessarily occurring in such experiments, which gives rise to these morbid changes. Division of the supra-orbital branch often produces amaurosis, a fact which cannot be satisfactorily explained. 3. Disease, such as softening of the portion of the brain where it arises, or tumours pressing on the nerve, produce complete anæsthesia of the whole side of the face, and in some cases the motor branch and the masticatory muscles are involved. If an object be pressed on the lips, the contact on the diseased side will not be perceived, and the patient often observes that there is a bit broken off the vessel he drinks from. The supra-orbital, infra-orbital, and mental twigs are the nerves affected in tic douloureux or facial neuralgia. This painful affection is often temporarily excited by some irritant, such as an ice in the stomach; and on the other hand the fifth nerve is very often the excitor nerve in many convulsive diseases which dentition gives rise to. It is also the exciter to

the function of respiration, and thus in cases of fainting we often induce an inspiration by dashing cold water on the face.

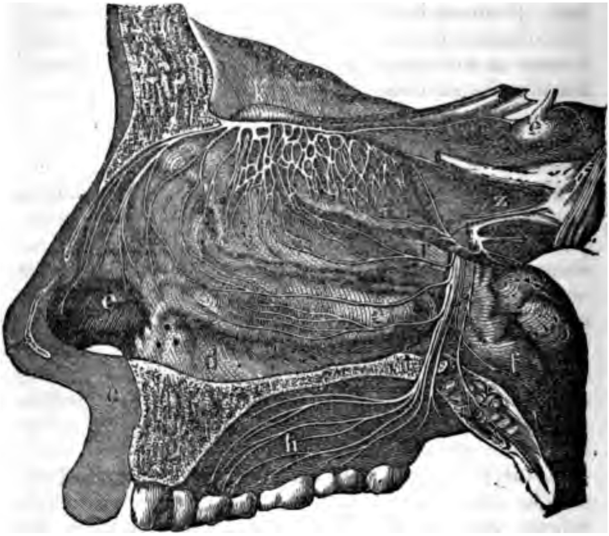
The Glosso-Pharyngeal arises in a grey mass within the olivary body, and passing between that body and the restiform, emerges through the jugular foramen, where it forms the ganglion of *Ehrenrittér*, and below this a larger one, that of *Andersch.* The nerve then runs with the stylo-pharyngeus muscle, and breaks into branches, for the muscles and mucous membrane of pharynx, and for the lingual papillæ. Those branches which go to the pharynx are purely sensitive, but either by mixing with some filaments from the spinal accessory or pneumogastric, or by referring an impression to the medulla, irritation of them produces motion of the pharynx. The glosso-pharyngeal is then the centripetal nerve of deglutition. We shall now discuss the question whether the gustatory or glosso-pharyngeal is the nerve of taste. *Valentin* asserted that the latter alone was the nerve of taste, as he found that sense was lost on its section. *Panizza* found that after section of these nerves dogs eat food mixed with colocynth, for which substance they have an extraordinary aversion. And again, the swan and parrot possess taste, although no branch of the fifth supplies their tongue. Experiments have, however, set the question at rest, for it has been proved that the gustatory nerve presides over taste in the anterior part of the organ, where the sense is more acute; and the glosso-pharyngeal at the back, which supplies the calyciform papillæ, where impressions are more enduring.

The Lingual nerve arises between the pyramid and olivary body, escapes through the anterior condyloid foramen, communicates with the cervical plexus and gustatory nerve, and supplies all the extrinsic muscles of the tongue. The lingualis or intrinsic muscle is supplied by the facial nerve, through the corda tympani, and is concerned in the exquisite movements of articulation, not those of mastication, which the other muscles are. The lingual nerve is then motor exclusively, and when divided, or injured by disease, the tongue becomes protruded towards the paralyzed side by the muscles of the healthy side. Paralysis of the lingualis, on the contrary, produces thickness of speech; and as its origin is intra-cranial, I have thus often been able to assign such a cause as softening of the brain for cases of paralysis of the muscles supplied by the seventh pair.

SMELL.

The nasal fossæ present an enormous mucous surface, from the windings of the spongy bones and the many sinuses which open into them. Air holding odours in suspension is admitted through the nostrils, the vibrissæ of which strain it of all foreign particles, or through the posterior nares when sapid and odorous bodies are in the mouth. The pituitary or Schneiderian membrane is ciliated in the lower portion of the nares and in the sinuses, and adheres most closely to the periosteum, which is, in fact, its basement layer. In the olfactory region, which includes the upper half of the septum, the roof, the upper spongy bone, and the upper half of the middle one, it is thick, soft, moist, of a sepia-brown colour, very vascular, and not ciliated. Under the membrane lie many glands, somewhat resembling sweat-glands, which pour out an abundant moisture, and crowds of varicose capillaries, looped like those of the skin, and which most readily pour out blood. Four nerves supply the apparatus of smell.

The Olfactory, or first cranial nerve, should be rather regarded as a ganglion connected with the corpus striatum in the fissure of Sylvius, the corpus callosum, and the anterior lobe by what are called its 3 roots. The prismatic band, so formed, dilates into a bulb, in which there is, in fœtal life and some animals, a ventricle communicating with the lateral ventricle. This bulb lies on the cribriform plate of the ethmoid, through which about 20 nerves stream down, forming a plexus and lash on the olfactory region, as here figured. In this nervous expansion there is no white substance of *Schwann*, but many gelatinous tubules, continuous with the vesicles in the olfactory bulb. It may be stated that some histologists regard these objects as mere bands of connective tissue, and not nervous at all, and they certainly do not degenerate after destruction of the bulb. The nerve now described is the special nerve of smell, and if it be divided that sense is at once and irrecoverably lost,



The Meatuses and Nerves of the Nasal Fossæ.

and disease of it has been found to impair or destroy the function. Its size is proportional to the acuteness of smell in various animals.

Bernard has, however, thrown doubt on the supposition that these nerves were essential to smell, for he found both olfactory bulbs and nerves congenitally absent in a subject he was dissecting in the Collège de France. On inquiring among the persons with whom the girl had lived, it was found that odours (such as those of flowers, tobacco, &c.) had affected her agreeably or disagreeably like other people. The nasal twig of the opthalmic division of the trifacial nerve is distributed generally over the mucous surface, and appears to preside over secretion of mucus, for dryness and subsequent loss of smell follows its section. From this experiment, *Magendie* regarded it as the special olfactory nerve; but the mere introduction of mucilage or glycerin restores smell after it is divided. This is the excitor nerve when irritant or pungent vapours are introduced, and it excites sneezing to expel them.

The naso-palatine nerve, a branch of *Meckel's* ganglion, confers common sensibility on the nose; and, lastly, the facial supplies some of the muscles on its outer surface, which are very ill-devoloped in man.

The Nature of Odours has not been positively ascertained. Odorous bodies are supposed to emit particles, which, conducted through the air, produce the sensation of smell by impinging on the olfactory surface. A grain of musk, however, was said to have lost nothing in weight appreciable to the nicest balance after having perfumed a large room, with open door and windows, for 10 years. Odorous substances must be presented in the gaseous state; for if applied in the solid form, or dissolved in water (except in the case of fishes), no sensation results. *Graham* believes that all odorous vapours undergo oxidation before they are perceived. The irregularity of surface of the spongy bone is designed to catch an odorous atom, in whatever way it may pass. The keenness of smell is such, that 1 part of sulphuretted hydrogen may be perceived, though diffused through a million parts of air, and we thus get warning to avoid its pernicious effects. The sense is developed in some animals in a higher degree; and in savage human tribes more remarkably than in civilized nations. *Humboldt* relates that Peruvian Indians can distinguish various races by smell. Repeated application of odours blunts the olfactory sensibility, and frequent exposure to dissecting-room effluvia has at least the advantage of rendering other putrid smells less disagreeable. In a similar way I would account for the poor being able to endure the stenches which arise in crowded unsanitary dwellings. Such odours may be observed to linger in articles of dress, especially those of dark cloth, for many days. As an instance of one odour being judged of variously by several persons, it may be stated that the iris smelt agreeable to 41 persons, disagreeable to 1, and was scarcely perceived by 4 others. Idiosyncrasies have been recorded towards various odours, and some morbid irritations have been said to produce imaginary or subjective sensations of smell. For the exercise of touch, taste, and smell, the actual contact of the excitant of each was necessary; not so in the case of the two exquisite organs of sense I have now briefly to describe to you.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Arrange, as sensitive and motor, the nerves supplying the organs of sense.
2. Describe briefly the cuticle and its appendages.
3. How would you demonstrate the tissues which are interwoven in the true sin ?
4. Describe a perspiratory tube.
5. What circumstances regulate the amount of sweat, and how was the quantity per minute measured ?

6. Describe the lingual papillæ.
7. Sketch briefly the distribution of the trifacial nerve.
8. Compare the mucous membrane in the upper and lower halves of the nose.
9. What four nerves supply the organ of smell, and what are their respective functions?

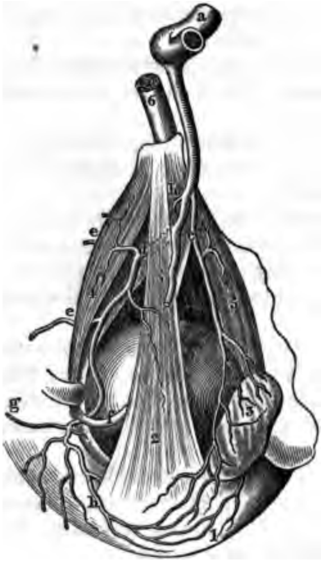
SENIOR.

1. Explain and exemplify objective and subjective sensations.
2. What are the peculiarities of the skin covering the palm of the hand, the sole of the foot, and the auditory meatus?
3. Describe the sensitive apparatus of the skin, and say how its activity may be estimated.
4. Does the skin absorb? Give proofs of your assertion.
5. What are the acids said to be found in perspiration.
6. Describe the nature of taste. Are sapid bodies crystalloid or colloid?
7. Is the gustatory or the glosso-pharyngeal the nerve of taste? Support your opinion by experimental facts.
8. Give the histology of the olfactory nerve, and reasons for and against regarding it as the sole nerve of smell.
9. Say what you know of the nature and properties of odours.

SIGHT.

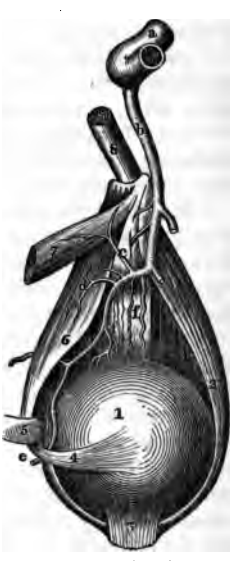
THE organ of vision is divided by anatomists into the eye and its appendages, including the eyebrows, eyelids, lacrymal apparatus, the bony orbit, and its muscles, nerves, and vessels. The eyebrow, a projection of skin beset with hairs, prevents sweat or falling bodies from dropping into the eye. The upper eyelid is larger than the lower, and consists of the following structures: thin skin connected to the orbicular muscle by fine areolar tissue, without fat; then the palpebral cartilage, covered on both surfaces, as *Sir P. Crampton* demonstrated, by the levator muscle; and, finally, the conjunctiva, which is reflected to the globe after forming a sinus, in which some suppose the tears course along. The Meibomian glands lie in the lids near the conjunctival surface, and they open behind the cilia at its edge. They are long, shrub-like follicles, analogous to the sebaceous glands, and they pour out an oily matter which prevents the adhesion of the lids or the overflow of tears. There are about 30 in the upper lid. The caruncle is a small mass of sebaceous glands which lies in the inner canthus, and pours out a white secretion; outside it is the plica semilunaris—a little fold rudimentary of the nictitating membrane, so highly developed in birds and some mammals. The lacrymal gland lies in the upper and outer angle of the orbit; it is about the size of a small bean, and in structure similar to the salivary glands, but has 6 or 8 ducts. The tears contain water and a little chloride of sodium, and mucus. After washing across the cornea, they pass into 2 small apertures—the puncta, which are kept open and apart by *Horner's* muscle, the tensor tarsi, which is composed of striped and very red fibres, and is supplied by the facial nerve. The tears flow through the puncta into the lacrymal sac, and then through the nasal duct, which, after running downwards and outwards for an inch and a-half, opens by a valve-like slit into the inferior nasal meatus.

The orbits are conical bony recesses, so arranged that great range of vision is allowed; thus, the eye can play 90° outwards, 60° inwards—comprising a horizontal range of 150°. Upwards it can be thrown 50 , and downwards 70°—a vertical range of 120°. In these cavities there are 7 muscles, 6 of which are attached to the globe of the eye. The 4 recti are fixed behind at the optic foramen, and are inserted in the sclerotic, about 4 lines behind the cornea. They can thus turn the eye in 4 directions, and can retract it within the orbital socket. The oblique muscles are 2—a superior, which runs through a beautiful pulley, which is for the purpose of reflecting its tendon towards the outer and back part of the eye, so that it can turn the cornea downwards and outwards; and the inferior, which is different from the other orbital muscles in arising from the anterior part of the floor of the orbit, and which turns the cornea upwards and inwards. Both oblique muscles can converge and advance the eyes, and can roll them on their antero-posterior axis. The orbital muscles and vessels are here represented. The motions of the eyeball are greatly facilitated by an admirable smooth capsule discovered by *Dr. O'Ferrall* of St. Vincent's Hospital. He exposed it by dividing vertically the lids and reflecting the segments; and by following these directions I



Contents of the Orbit.

a. *Internal carotid giving off ophthalmic.* 2. *Elevator of the upper lid.* 3. *Lacrymal gland.* 4. *Superior oblique.* 5. *External rectus.* 6. *Optic nerve.*



Deeper Dissection.

1. *Globe.* 2. *External rectus.* 3. *Section of Superior rectus.* 4-6. *Superior oblique.* 5. *Its pulley.*

have always succeeded in demonstrating it to the class at the Royal College of Surgeons. In an exhaustive paper in the "Dublin Journal of Medical Science," July, 1841, its discoverer thus sums up its physiological and pathological relations: "The reflections suggested by a review of the cases which led to the present inquiry, as well as of this new and curious mechanism itself, may be reduced to the following propositions:

"1st. That the description of anatomists, which places the globe of the eye in contact with the fat and muscles of the orbit, is erroneous.

"2nd. That there exists a fibrous tunic, investing and insulating the eyeball, and separating it from all the other structures in the orbit.

"3rd. That the uses of this tunica vaginalis oculi are to present a smooth surface, facilitating the movements of the eye, and, by its density and tension, to protect it from the pressure incidental to the swelling of the muscles during their action.

"4th. That the openings in this tunic perform the offices of pulleys—giving a proper direction to the force exerted by the muscles, securing the motions of rotation, and of opposing those of retraction, which would otherwise predominate.

"5th. That certain cases of disease within the orbit, accompanied by protrusion of the eye-ball, are to be explained only by reference to the tunica vaginalis oculi, and the other fibrous tissues now described.

"6th. That a correct knowledge of the anatomy of the orbit, and of the fibrous structures alluded to, is essential to the operating surgeon in dealing with abscesses and tumours, in extirpation of the eyeball, in the operation for strabismus, and all operations on that cavity."

I will return to the pathological aspects of this structure in the second section of this work.

In the cuttle-fish a serous sac lies between the eye and its orbit; this has been described as the analogue of the conjunctiva by *Cuvier*, and of the membrane of the aqueous humour by *Owen;* but it seems to me closely to resemble the tunica vaginalis oculi.

The cranial nerves accessory to vision are the oculomotor, trochleator, ophthalmic division of trifacial, abducens, and facial, and the sympathetic also contributes some filaments.

The Oculo-Motor, or 3rd nerve, arises in the locus niger of the crus cerebri, and just behind the orbital foramen, splits into an upper and lower branch, which are respectively distributed to the levator palpebræ and superior rectus, and to the inferior oblique, internal and inferior rectus. By sending the motor twig to the lenticular ganglion, it supplies the circular muscular fibres of the iris and the ciliary muscle. The nerve is purely motor, as shown by its distribution, and by its size being proportioned to the development of the muscles in various animals; thus, in the falcon, which has powerful iridal and ciliary muscles, the nerve is as large as in man. Its function is also demonstrated by galvanic stimulation and section. It presides over contraction of the pupil—being thus antagonistic to the sympathetic—over adjustment, and produces convergence of the eyes, which always concurs in near vision. As the eye is turned upwards and inwards, and the pupil contracted during sleep, it is supposed to be then still in action. Disease of the nerve is indicated by ptosis, divergent strabismus, mydriasis, or dilated pupil, and—as I lately ascertained in a patient of mine in St. Vincent's Hospital—by impaired ocular adjustment. Belladonna produces precisely similar effects. The calabar bean, either by stimulating the third nerve or paralyzing the sympathetic filaments, contracts the pupil so powerfully, that it may be used to break adhesions which remain after iritis.

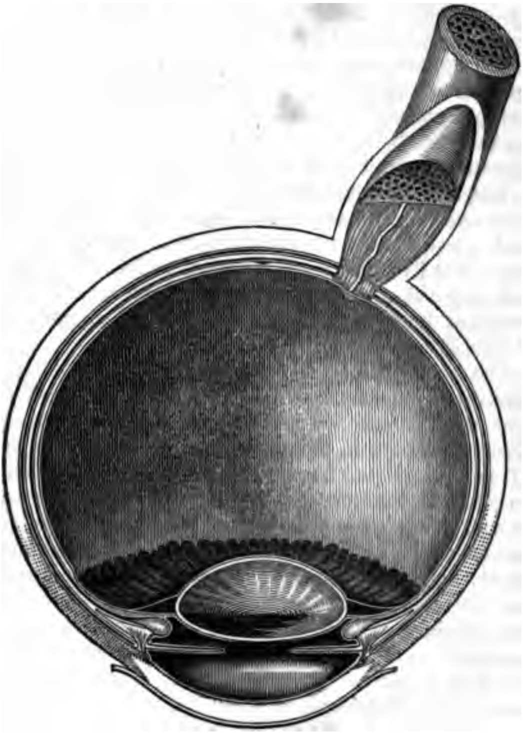
The Trochleator, or 4th nerve, is a very fine, long band arising from the roof of the 4th ventricle and the superior cerebellar peduncles, and distributed to the orbital surface of the superior oblique muscle, which it alone supplies. *Sir C. Bell* calls it "the respiratory nerve of the eye," and says it is large in all animals capable of much expression. The opthalmic, the sensitive nerve of the eye, and all its appendages, has been already described (p. 347).

The Abducent, or sixth nerve, emerges between the pons and pyramid, and after a very free communication with the sympathetic in the cavernous sinus, supplies alone the external rectus, and is thus purely motor. The nerve has been found injured or compressed in cases of convergent strabismus. The facial nerve will be afterwards described—but it may be here mentioned that it supplies the orbicularis and tensor tarsi muscles, so that division of it is followed by open eye (lagophthalmos), and overflow of tears (stillicidium), and stimulation by spasmodically closed lids (blephrospasmus), and dryness of the eye. The influence of the sympathetic on the movements of the iris and the vascular supply, has been alluded to at page 293.

The Human Eye is almost a globe, its transverse and vertical axes measuring about an inch, and its antero-posterior diameter being 14 lines, owing to the projection of the cornea. Its parts are divisible into—1. Coats, or protective structures; 2. Dioptric media; and 3. Nervous or percipient apparatus. In the annexed representation of a horizontal section of the eye-ball, all the parts are kept proportionably equal.

The Sclerotic is composed of white fibres interwoven in every direction, but leaving a few spaces, probably nutritive, between them, and forms a hollow sphere of such toughness and resistance that it retains its shape when emptied of contents. It is covered anteriorly by the tendinous expansion of the 4 recti (tunica albuginea), which gives it a whiter tint, and thickens it. It is thickest at the entrance of the optic nerve, and thinnest

2 lines behind the cornea, where rupture has occasionally occurred. The openings in this coat are, that for the



Section of the Human Eye.

The following parts would be pierced by a needle from before backwards:—conjunctiva, anterior elastic cornea, laminated cornea, posterior elastic cornea, the aqueous humour and its sac, capsule of lens, lens, capsule. The needle, if in the axis of the eye, would traverse the hyaloid canal, and emerge through the punctum aureum. If laterally, the following coats would be pierced, vascular, nervous, and Jacob's layers of the retina, pigmentary, arterial, and venous layers of choroid, and the sclerotic.

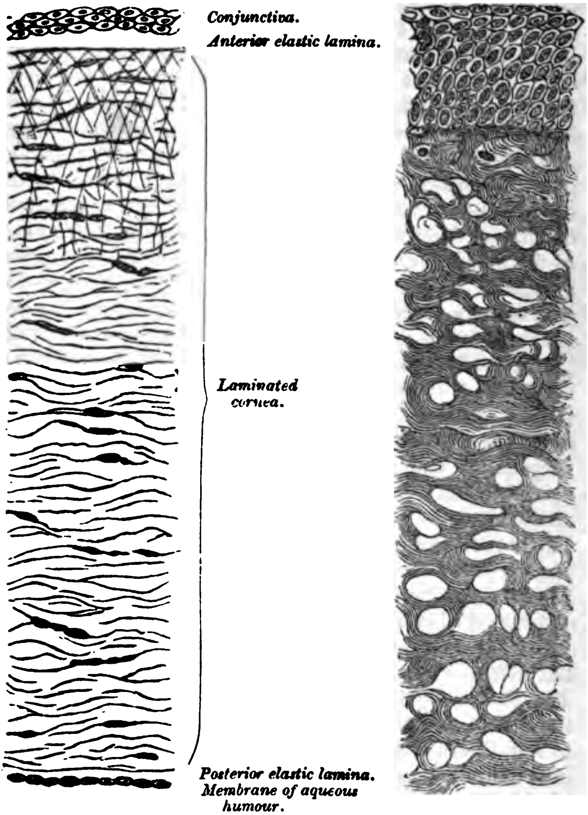
insertion of the cornea, for the entrance of the optic nerve, and small appertures to transmit the ciliary nerves and vessels which supply the organ. The sclerotic is cartilaginous in many animals, and bony in the sea-bream, as discovered by *Dr. Jacob.*

The Cornea is exquisitely transparent, hence the term "pellucida," applied to it in contra-distinction to the "cornea opaca," or sclerotic. It is circular posteriorly, but in front, being overlapped above and below by the sclerotic, is about $\frac{7}{16}$ of an inch transversely, according to frequent measurements, and a little less from above downwards. The cornea and sclerotic thus form respectively $\frac{1}{5}$ and $\frac{4}{5}$ of the circumference of the globe. *Bowman* states that its anterior and posterior surfaces form similar and equi-distant curves; whereas *Jacob* regards it as a meniscus lens, thicker in the centre, and, as noticed by *Haller*, it certainly magnifies letters.

The cornea can be divided into 5 layers: 1. The conjunctiva, a mucous epithelium which is prolonged from over the sclerotic; it is most readily demonstrated by plunging the eye in boiling water, when it can be peeled off as a coagulated film. The eye of the cuttle-fish has no other cornea than that which the common integument forms; the serpent's slough includes a skin from the cornea, and in the mus typhlus or mole-rat, according to *Jacob*, hairs grow from it. Some cutaneous eruptions and phlyctenular ophthalmia raise up the conjunctiva; and particles of iron and other foreign bodies are often impacted in it: this is the only layer of the cornea which is sensitive. 2. The anterior elastic lamina was first clearly described by *Bowman.* It is hyaline, exquisitely transparent, and of high refractive power, so that it sparkles in water. It is scarcely acted on by any reagent, but yields, by prolonged boiling, a matter more like chondrin than gelatin, and peculiar in being soluble in excess of its precipitants. Although thicker ($\frac{1}{2000}$) than the posterior elastic lamina, it is much less easily separated, as it is tied to the next layer by many curved fibres ; but by prolonged maceration I have often succeeded in separating it in the horse's eye. 3. The proper or laminated cornea consists of many fibrous layers, the spaces between which are tubular, as demonstrated by *Bowman*, who with mercury has injected these "corneal tubes." They are probably nutritive canals for the cornea, which so far from being non-vascular heals after operations with surprising rapidity. Neither is it without nerves, for microscopists have lately found branching nerve-tubes in this layer. Owing to the laminated arrangement, the cataract needle is more apt to slip between the layers than to pierce them if the operator be not careful. This layer becomes opaque by stretching it, or by pressure on the globe of the dead eye. 4. The posterior elastic lamina or membrane of *Demours* and *Descemet* is quite similar to that already described, and with it admirably preserves the due curvature of the cornea. 5. The epithelium of the aqueous humour constitutes the last plane of the cornea, and it can scarcely be traced farther in the anterior chamber. The anterior and posterior elastic laminæ seem to me to be but the basement layer of the conjunctiva and membrane of the aqueous humour respectively, and thus the cornea consists of 3 essential structures—the conjunctiva prolonged from the sclerotic, the proper cornea continuous with this coat, and the membrane of the aqueous humour, all somewhat modified to suit special purposes. The five layers can be distinguished in the annexed section by *Mr. Richardson*, who in an able paper (*Dublin Journal*, February, 1859) has discussed the changes which staphyloma produces. The second figure illustrates the confused condition of the cornea and anterior chamber in that disease.

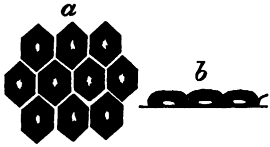
The Choroid and its appendage, the iris, form the next plane, a very fine areolar web—sometimes named the "tunica arachnoidea oculi," or "membrana fusca"—in some places intervening. To convey clear ideas of this coat and the method of demonstrating it, I cannot do better than quote *Dr. Jacob's* accurate description:

"This membrane is of a deep brown or black colour, being stained with the colouring matter called the black



Healthy and Staphylomatous Corneæ.

pigment; but when this is removed, it exhibits a high degree of arterial and venous vascularity. Its external surface is comparatively rough, coarse, and flocculent, and obscured by the cellular membrane which connects it to the sclerotic. The inner surface, which is in contact with the retina, presents a very different appearance. It is soft and smooth, and when minutely injected resembles the more delicate mucous membranes, and exhibits a remarkable degree of minute villous vascularity. The external surface being composed of the larger branches of arteries, veins, and nerves, may be torn away from the soft, smooth, and more closely interwoven inner layer; or the inner layer may be partially dissected up from it, with some care, especially in the eyes of the larger quadrupeds. This manœuvre having been executed by *Ruysch*, and preparations so formed displayed by him, the inner layer has been denominated the tunica Ruyschiana. But this is a mere anatomical artifice. There is no natural division into two layers, the soft, smooth, and highly vascular inner surface being formed by the ultimate subdivision and distribution of the larger branches of vessels, which exhibit themselves separately on the outside. It is a condition somewhat analogous to that of the skin, where the soft, smooth, villous external surface presents so remarkable a contrast to the rough internal surface, with its layer of cellular membrane uniting it to the subjacent parts."



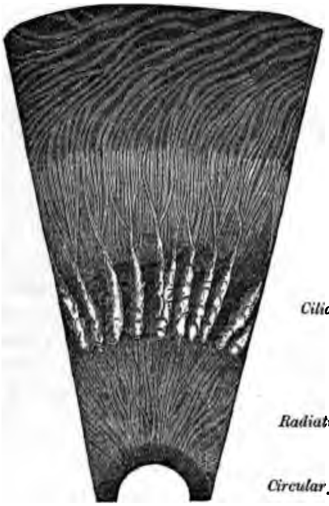
Pigment Cells of Choroid.
a. Horizontal view. b. From side.

The arteries are the short ciliary branches of the ophthalmic, and the veins, which are branched like the boughs of the weeping willow (vena vorticosa), end in the ophthalmic vein. The inner layer is a sheet of beautifully regular hexagonal cells, discovered by *Wharton*

Jones, and in these are deposited brown pigment granules, which contain iron. The membrana pigmenti has no colouring matter where it lies before the tapetum lucidum of many animals, nor in the albino, and can be best examined in the white rabbit, which affords a frequent example of that condition. The centre of each cell is lighter in colour, and depressed, corresponding to the elevations of the rods of *Jacob's* membrane.

Between the anterior edge of the choroid and the iris lies the ciliary body, which consists of about 70 triangular folds, alternately long and short, corresponding to similar plaits on the vitreous membrane. These, which are distinguished as ciliary processes, do not quite reach the edge of the lens, but a small triangular space intervenes, which *Petit* discovered, and named the "canal godronné." The ciliary ligament unites the choroid and iris, as well as the cornea and sclerotic, forming between them a common welt of fusion. *Sömmering* regarded it as ganglionic, as he could trace nerves into it, not out of it; and *Fontana* found it permeated by a circular canal uniting the long ciliary arteries. Its true structure was, however, stated by *Porterfield* to be muscular, and *Sir P. Crampton* found striped fibres in that of birds. This ciliary muscle is accurately described by *Bowman* as arising at the joining of the sclerotic and cornea, and after radiating backwards, it is inserted into the ciliary body. The nerves going to the iris pierce it and supply it. We shall presently discuss its function—namely, the adaptation of the eye to near and distant objects.

The Iris is a circular curtain, attached by its outer margin to the cornea, the posterior elastic lamina being continued for a short distance on it, to the ciliary ligament, and lastly to the ciliary processes, which adhere to its posterior surface so as to leave only that portion around the pupil free. The back of the iris is stained by the pigment, and is termed "uvea;" whereas the anterior surface, from its varied hues, gives it its name. Pigment cells are mixed in the tissue, and give the well-known grey, blue, hazel, or dark brown tints. *Jacob* describes many fibrous lines on the anterior surface converging towards the pupil, near which they form a thick knotted circle; and if the pigment be removed from the back, they resemble the carneæ columnæ and cordæ tendiniæ of the heart. They are straight when the pupil is contracted, zig-zag when it is dilated. Other fibres are woven round the pupil, thickening the iris at its margin, and forming the "sphincter iridis" of *Cloquet*. The radiating fibres dilate and the circular contract the pupil to a diameter ranging from $\frac{1}{3}$ to $\frac{1}{20}$ of an inch. The nervous supply of the radiating muscle is



Segment of the Choroid, Ciliary Processes, and Iris.

from the sympathetic, and that of the circular from the oculo-motor nerve, as before stated. The vascular supply is derived from the two long ciliary arteries, which form 2 or 3 circles before they reach the pupillary edge. That the anterior ciliary arteries from the muscular branches of the ophthalmic also supply it, their great injection in iritis proves. So vascular is the iris, that *Ruysch* believed its movements to be due to erection. *Fontana* and *Dr. Paxton* are said to have had voluntary power over the iris.

The dioptric media or lenses of the eye are the aqueous humour, the crystalline, and the vitreous body.

The Aqueous Humour fills the anterior and posterior chambers, which communicate, save in fœtal life, through the pupil. This aperture is closed till the 9th month by the membrana pupillaris, which some regard as the apposition of two small sacs which line the anterior and posterior chambers; but it is only on the back of the cornea any epithelium can be found in adult life. The pupillary membrane is, as it were, a scaffolding for the formation of the iris, which, owing to the absence of light during intra-uterine life, would contract up towards the ciliary ligament. The anterior chamber is convex towards the cornea and plane towards the iris; and the posterior, which is much smaller, both transversely and antero-posteriorly, is bounded behind by the lens, canal of *Petit*, and the ciliary body. The aqueous humour contains but 2 per cent. of solids—chiefly chloride of sodium. It constitutes a converging lens, but in addition is thought to facilitate the motions of the iris, for it exists in fishes, where, from the equal density of the surrounding water, it can have no refracting power. When removed in operations, it is soon re-secreted.

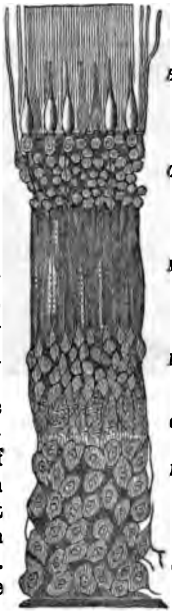
The Crystalline is a bi-convex lens with the posterior curvature the greater. In the fœtus it is almost spherical and touches the iris, and then gradually flattens during the rest of life. Its diameter is about ⅓ and its axis about $\frac{1}{6}$. The lens is enveloped in a capsule of a hyaline substance like the elastic layers of the cornea, permeable to fluids and dissolving by prolonged boiling. It is 3 or 4 times as thick in front as behind, where the vitreous body into which the lens is set affords support. Between the capsule and the lens lies a layar of nucleated cells, which soon after death melt down into what was called the "liquor Morgagni;" but *Brücke* doubts their existence altogether. The lens weighs about 3 grains, and contains 35 per cent. of albumen or crystallin.

The histology of this apparently simple body is full of wonder. If hardened in spirit, it readily breaks on the anterior surface into three equal triangular portions, with the apices towards the centre. It is similarly divisible on the back—the intervals, however, corresponding to the middle of each anterior segment. From these lines fibres about $\frac{1}{5000}$ in width pass in various planes from one surface to the other, becoming shorter and thicker towards the centre. *Sir D. Brewster* discovered that these fibres were jointed by serrated edges, especially distinct in fishes; and *Kölliker* believes them to be tubular. The lens can thus permit of osmose, and to some such change the opacity we term idiopathic cataract appears due, for that disease may be produced in frogs by merely placing strong saline solutions in the intestines, or in any animal by injecting, through the vessels of the lens, saccharine solutions. The concurrence of diabetes, in which the blood has a high specific gravity, and cataract, to which *Richardson* has drawn attention, may have some relation to these facts; and the cataract of old age and infancy may respectively depend on deficiency or excess of water. The density of the lens increases from the surface, where its refractive index is 1·3767, to the centre, where it is 1·3990. A large branch from the central artery of the retina reaches the back of the lens in the fœtus, and remains pervious in many large animals, and a few vessels from the ciliary processes also feed it.

The Vitreous Body—the last dioptric medium—is a jelly-like mass filling the posterior $\frac{4}{5}$ of the globe. It consists of a membrane which sends in many processes, forming areolæ infiltrated with water, so that a puncture does not evacuate the fluid at once, but it slowly drains out. The structure of it is very similar to that of the jelly-like matter round the umbilical cord. It has been said to be arranged in laminæ; but despite most careful examination, it seems as hyaline as the disc of the medusa. The vitreous membrane is plaited on its front, producing an appearance named the "Zonula of *Zinn.*" The ciliary processes of the choroid dovetail with these folds, and within them the mass is hollowed to receive the lens, to the capsule of which many of its fibrous processes are attached. The refracting power of this medium is 1·339, or a little above that of water.

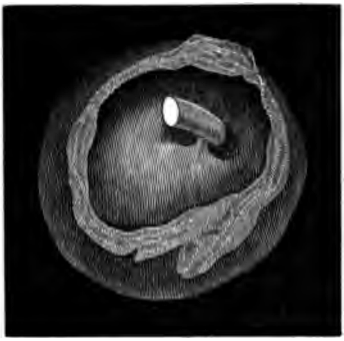
The Retina is the essential part of the organ of vision, as upon it is thrown the optical image, the impression of which is then conducted back to the brain. Commencing at the entrance of the optic nerve it spreads forwards, becoming gradually thinner, and ends by a wavy border (ora serrata), a line and a half short of the ciliary ligament. Its hollow, spherical form is preserved by the vitreous body, for it collapses at once if this be removed. Examined from within outwards, it consists of the following layers: 1. The vascular, derived from the central artery. 2. The fibrous, consisting of the tubules of the optic nerve spread out, having previously lost the white substance of *Schwann*, which in the rabbit is still retained. As these fibres stream through the aperture for the optic nerve, there can be no other nervous matter behind them, which accounts for this spot being destitute of vision, as they do not constitute the percipient structure. 3. The vesicular layer, consisting of vesicles similar to, but smaller than those of the brain. As the tubes of the last described layer waste after section of the optic nerve, they are not derived from the vesicles.

4. A thick granular layer of the function, of which we are ignorant: and 5. The membrana Jacobi, which its discoverer, *Dr. Jacob*, Professor of Physiology in the Royal College of Surgeons, first described in the "Philosophical Transactions," 1819. His mode of preparing it is as follows:



Section of the Layers of the Retina, after Kölliker.

"Having procured a human eye, within forty-eight hours after death, a thread should be passed through the layers of the cornea, by which the eye may be secured under water, by attaching it to a piece of wax previously fastened to the bottom of the vessel—the posterior half of the sclerotic having been first removed. With a pair of dissecting forceps in each hand, the choroid coat should be gently torn open and turned down. If the exposed surface be now carefully examined, an experienced eye may perceive that this is not the appearance usually presented by the retina. Instead of the blue-white reticulated surface of that membrane, a uniform villous structure, more or less tinged by the black pigment, presents itself. If the extremity of the ivory handle of a dissecting knife be pushed against this surface, a breach is made in it, and a membrane of great delicacy may be separated and turned down in folds over the choroid coat, presenting the most beautiful specimen of a delicate tissue which the human body affords. If a small opening be made in the membrane, and the blunt end of a probe introduced beneath, it may be separated throughout without being turned down, remaining loose over the retina; in which state, if a small particle of paper or globule of air be introduced under it, it is raised so as to be seen against the light, and is thus displayed to great advantage; or it is sometimes so strong as to support small globules of quicksilver dropped between it and the retina, which renders its membraneous nature still more evident. If a few drops of acid be added to the water after the membrane has been separated, it becomes opaque and much firmer, and may thus be preserved for several days, even without being immersed in spirit."



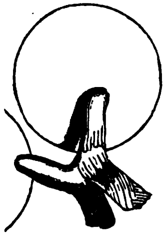
Jacob's Membrane detached.

Dalrymple next described it as a serous sac, lining the choroid and retina. It is composed of rods which readily separate from each other, and the outer end of each is curved into a crook; from this appearance it has been called the bacillar layer. Some of the rods take a radiating direction.

In the centre of the retina is the "punctum aureum," or yellow spot, which *Sömmering* discovered, in 1791, in a young man drowned in the Rhine a few hours before. The vessels and nerve-tubes of the retina do not pass over it, but curve about it. The spot has decidedly a small aperture in its centre, for through it the interior of the eye can be seen. A yellow pigment, which water will dissolve out, gives a golden halo round it, so that its diameter exceeds half a line. *Jacob's* layer is continued across it and the colour is much brighter when it is removed. It has been only found in man, quadrumana, and a few reptiles; so that *Sir E. Home's* theory—that through it the absorbents entered—seems improbable. In an erudite paper in the "Atlantis," July, 1858, *Prof. Hayden,* of the Catholic University, thus expresses his opinion upon its function:

"I have been led to the conclusion that unity of visual perception with two eyes is inseparably associated with the yellow spot of *Sömmering,* and may invariably be inferred from its presence, and that this property is limited to a circle, having as its centre the foramen centrale, and a radius of about ·04 inch. This circle I propose to designate as the 'region of visual unity,' within which the rays of light proceeding from an object must fall, in order to produce a single perception from a binocular impression. Outside this circle, and concentric with it, is another, having a radius of 0·533 inch: the latter I would name the 'region of visual duality,' because I believe that the image of an object depicted within it, and outside the region of unity in both eyes simultaneously, produces a double perception in the sensorium. That portion of the retina extending from the region of duality to the ora serrata, is probably insensible to luminous impressions, and serves some other purpose in the economy of the eye, with which we are still unacquainted."

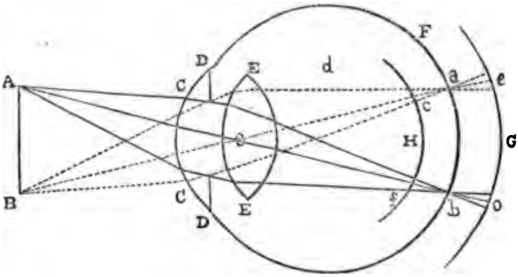
The Optic Nerve arises by the optic tracts from the quadrigeminal bodies and thalami. The tracts wind round the crus cerebri, being flattened against it by the middle lobe, and, on the olivary process, form with its fellow the optic commissure. In this body, besides a few vesicles which give it a glanglionic character, there are 4 kind of tubules: 1. Those which pass from one tract, along the outer side of the corresponding nerve, to the eye of the same side. 2. Those which cross from one tract through the commissure to the opposite nerve, and are by far the most numerous. 3. Those which run from one tract back to the other, being thus intercerebral, and present in such animals as the mole, in which the optic nerves are wanting. 4. Those which are inter-retinal, by passing from one nerve to the other, and which were first described by that able physiologist and great physician whose loss we have recently had to deplore, *Dr. Mayne*, in *Todd's* "Cyclopædia." In the cod, all the fibres of one tract pass to the opposite nerve. *Wollaston*, in order to account for single vision with 2 eyes, stated that all the fibres of one optic nerve—say, the right—go to the right side of both the right and left eyes. As the optic nerve enters the optic foramen, the dura mater sends a strong sheath about it, which joins the sclerotic and dips down through the fibres, producing the appearance, at the entrance into the eye, of a "lamina cribrosa." The nerve suddenly diminishes before it passes through, owing to the white substance of *Schwann* ceasing, and ends by a small papilla, which is marked by the porous opticus, a spot produced by the central artery. The optic nerve enters about 1½ lines to the inner side of the central axis, as it follows the direction of the orbit, whereas the eyes are parallel in man. *Dr. Power*, when lecturer on Anatomy in the Richmond Hospital School, discovered in the loligo and other animals, that the fibres of the optic nerve decussate behind the sclerotic, and he thinks this anatomical arrangement may explain erect vision, and "that the correct impressions made upon the sensorium is the result of the rays of light impinging on the terminations of the nervous fibres in the retina, which, crossing each other in their course backward, run to be attached to opposite points of the sensorium." The arrangement, however, cannot be discovered in many animals, and to render the explanation satisfactory, the fibres should be shown to decussate in every direction. His valuable memoir may be found in the "Dublin Journal of Medical Science," 1843, and one of the figures from it is here reproduced.


Decussation of the Fibres of the Optic Nerve.

Light.—The properties of light will be briefly discussed before considering the mechanism of that most admirable of optical apparatuses, the human eye. *Sir I. Newton* believed light to be an emission of particles from a luminous body; whereas, strangely enough, he applied the second theory, which is now more generally accepted, to another imponderable—sound. *Boyle* also suggested a molecular theory. *Huygens* first suggested that light consisted in a succession of waves from the luminous object, and this theory has obtained powerful support from the great work of the *Rev. Dr. Lloyd,* Vice-Provost of Trinity College, Dublin. Light travels with such rapidity that it is supposed to pass from the sun to the earth, a distance of 95,000,000 miles, in 8 min. 13 sec., or at the rate of 191,515 miles per second. Light is not homogeneous, but if passed through a prism is decomposed, owing to their unequal refrangibility, into 7 primitive colours—namely, violet, 109; indigo, 47; blue, 48; green, 46; yellow, 27; orange, 27; red, 56. The numbers after each indicate their proportion, if the spectrum be supposed to measure 360. According to *Sir David Brewster,* it is composed of 3 primary colours—blue, yellow, and red. If these colours of the spectrum be passed through another prism, they are re-composed into white light.

A ray of light falling on a polished surface is reflected or thrown back at an angle, which is equal to that of incidence. If it falls on a transparent medium, it is refracted or bent towards the perpendicular if the medium be denser than that it passed through before—from the perpendicular, if it be rarer. If the ray falls at right angles, no refraction occurs. The degree of refraction varies with the density of the medium, and also with obliquity with which the ray falls; if, therefore, a pencil of ray falls on a convex lens, the central ray will pass through unaffected, and those farthest from the centre will be most refracted, as they fall with greatest obliquity upon the lens. When the rays emerge from a bi-convex lens into a rarer medium they will converge towards the central ray; and at this point, termed the focus, an image of the object from which the rays were originally given off will be formed. Six kinds of lenses are described, the first 3 of those below named being convergent or collective—the last 3 being divergent or dispersive. They are as follows: bi-convex, plano-convex, meniscus; bi-concave, plano-concave, concavo-convex. The central line passing through them is termed the axis. The application of these laws of light to the eye is clearly stated by *Todd* and *Bowman:*

"If a luminous object, as the flame of a candle, be placed eight or ten inches in front of the organ, some rays fall on the sclerotic, and are reflected; the more central ones fall on the cornea; some are reflected, and others pass through it, are slightly converged by it, and enter the aqueous humour, which being probably of the same refracting power, does not alter their course. Passing onwards, some meet the iris and are absorbed or reflected by it, whilst others advance through the pupil. Thus, rays falling on a large extent of the cornea, are converged so as to fall on the lens. By the convexity of the surface of the lens, as well as by the greater density of that body towards its centre, this convergence is much increased. Lastly, by their passage into the rarer medium of the vitreous humour, the rays are further converged by the refraction of each ray from the perpendicular to the point of incidence, and the several pencils which they form are brought to as many foci in the retina. And still further, the rays from the opposite points of the luminous object, by reason of the change of direction which they undergo through these successive refractions, cross one another (the angle of crossing being called the "visual angle"), and thus the image of the flame on the retina appears inverted." A careful study of the foregoing figure from *Müller* will make these principles intelligible.



The Course of the Rays through the Eye.

The rays from the object A B are refracted by the cornea C C, the aqueous humour, and still more by the lens E E and the vitreous humour behind it. They are thus collected to points at a and b, and the retina F being here situated, perfect pictures of these points, though reversed, are seen. If the retina be, however, in front (H), or behind (G) these points of convergence, luminous circles instead of points will be seen at c and f, or e and o, and no defined image will be produced.

The Adaptation to vision at various distances is one of the most remarkable properties the eye possesses. It has been supposed to be due to the recti muscles compressing the eye-ball, and making the cornea more convex when looking at near objects, or to the lens being moved forwards by the contraction of the iris or ciliary processes. The adjustment, is, however, accomplished by the ciliary muscle moving forwards the lens, which afterwards falls backwards by the elasticity of its "suspensory ligament," or the anterior wall of the canal of *Petit*. The eye is therefore in a state of repose when viewing distant objects, but a muscular effort is required to look at a near one. This power is impaired by the action of belladonna or disease affecting the oculo-motor nerve, and is lost when the lens is extracted—to which statement, however, I have known of an exception.

Myopia, or near-sightedness, depends on too great refracting power, so that the image is formed in front of the retina; it occurs mostly in youth, but does not disappear as age advances, as commonly supposed. Concave glasses cause the image to be thrown farther back, but they tend to increase the defect.

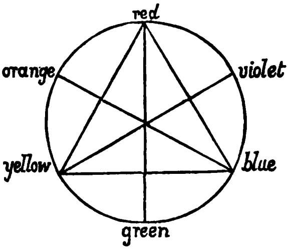
Presbyopia, or far-sightedness, the opposite defect, in which near objects are not perceived, depends on too great flatness of the cornea or lens, a result of old age. Convex glasses remedy it by increasing the convergence of the rays; but if not carefully adjusted they may produce the opposite defect, and as the two eyes often differ in their refracting power, it is often impossible to make a pair of spectacles suit exactly. The diagram on page 375 will enable the student to comprehend the physics of long and short-sightedness.

Spherical Aberration, which should result from the fact before stated, that rays falling on a convex lens must be unequally refracted, is remedied by the iris, which, like the diaphragm of a telescope, shuts out the circumferential rays, and the density and refracting power of the lens increasing towards the centre. The iris also is of use in shading the retina from too strong light, and it acts in reflex obedience to that sensitive surface. In amaurosis, when the retina is insensible, the pupil dilates.

Chromatic Aberration is a fault due to the partial decomposition of the light while passing through a convex lens, but it is obviated in the eye and optical instruments modelled after it, by the varying densities of the media through which a ray necessarily passes. *Sir D. Brewster* believes this colouring does occur in the eye, and it certainly does when fatigue, belladonna, or pressure on the eye-ball deranges its exquisite mechanism. Some of the rays of light which impinge on the retina become reflected therefrom, as the lustre at the back of the eye in some people shows; but in many animals this occurs to a great extent, as there is the mirror-like tapetum lucidum outside the retina. The images formed in *Purkinje's* catoptric test for cataract are due to reflexion. That valuable method of ascertaining the presence of cataract or glaucoma is performed as follows: the pupil having been dilated by belladonna, the patient is placed in a dark room; a candle with a steady flame is held before the eye, and if it be healthy, 3 images of the candle are seen—the first erect on the cornea, the second reversed on the front of the lens, and the third erect behind it. When the candle is moved the erect images move in the same direction, the inverted one in the opposite direction. Cataract removes the middle or inverted one, and renders dim the deep one; while glaucoma renders more evident the deepest image. If the sclerotic and choroid be removed from the back of the eye, an image of any object placed before it is thrown on the retina, as on the screen of a camera obscura; but this probably does not occur in the living eye, as then the retina is as clear as glass.

As regards the real percipient of the optical image, the opinion that *Jacob's* layer has this function is gradually gaining ground. It has been urged by *Donders*, who has convinced himself that the yellow spot is also perceptive. *Prof. Draper* thus expresses himself: "Considering, therefore, the retina as typically composed of three layers—one of tubules, one of vesicles, and one of granules, and these in health being perfectly transparent, the luminous beams pass through them, just as they do through the atmosphere, without exerting the slightest effect; and as, when those rays strike the opaque surface of the earth, or are absorbed by the sea, heat is disengaged and effects ensue, so likewise when they have reached the black pigment, the changes I have been designating arise. The vesicular layer undergoes rapid metamorphosis, the effect of that change is transmitted by the tubular layer, and in the granular the germs are constantly arising from which the waste of the middle layer is repaired. So, therefore, the tubular layer is for conduction, the vesicular layer for waste, the granular layer for repair; and now appears the significance of the construction and proximity of the choroid coat, for the waste of the vesicular layer cannot occur save under the oxidizing influence of the arterial blood, nor can the nutrition of the granular layer be accomplished, except under the same condition. Moreover, the resulting products of waste require to be quickly removed, and it is not possible to conceive the construction of an arrangement better adapted for this triple object than that which the choroid presents." The retina of the cuttle-fish consists of two layers, with the pigment interposed.

That images endure for some time is shown by a lighted stick, if rapidly whisked round, appearing as a luminous circle, and by the closure of the lids, in the rapid movement of vision, not interfering with continuous vision. The image remains on the retina about ⅛ of a second, more or less according to the time it has been previously applied and to its intensity. Ocular spectra, or after-sights, are due to the image still persisting after the object has been withdrawn from the field of vision—or may be due to centric causes, which, as is the case with other special senses, will give rise to subjective sensations. Spectra are usually of the complementary colours—thus, green, if the image was red; yellow, if violet; orange, if blue. The accompanying figure, from *Müller*, shows the simple and compound colours, and those which are complementary of each other: "The three simple colours, red, yellow, and blue, are placed at the angles of an equilateral triangle, which are connected together by means of a circle; the mixed colours — green, orange, and violet—are placed intermediate between the corresponding simple or homogeneous colours; and the complementary colours—of which the pigments, when mixed, would constitute a grey, and of which the prismatic spectra would together produce a white light—will be found to be placed in each case opposite to each other, but connected by a line passing through the centre of the circle. The figure is also useful in showing the further shades of colour which are complementary of each other. If the circle be supposed to contain every transition of colour between the six marked down, those which, when united, yield a white or grey colour, will always be found directly opposite to each other; thus, for example, the intermediate tint betwen orange and red is complementary of the middle tint between green and blue."



The blindness of the entrance of the optic nerve (punctum cœcum) is proved by *Mariotte's* famous experiment, which may be performed as follows: place both thumbs together at arm's length, shut the left eye, and with the right look fixedly at the left thumb; if the right be now moved slowly outwards, its image will not be perceived as it passes over the entrance of the optic nerve, but will afterwards re-appear. It has been said that if this insensible point existed, there would be a dark spot in the field of vision whenever we used but one eye; but
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as we require nerves to tell us of cold, or the absence of heat, to be aware of the darkness, or absence of light, we would require nervous matter, which is here deficient. As the optic nerves do not enter the centres of man's parallel eyes, the blind spots never correspond.

By the action of the lenses, the picture is reversed on the optical screen, but the mind nevertheless perceives the object in its natural erect position. *Müller* obscurely says that there is no need of correction, as, if all objects do really appear inverted, their relative position is unaltered. If, besides the vertical decussation—which, as we have before noticed, *Prof. Power* discovered in a few animals—there was an interchange of the fibres of the optic nerve in every other direction, it would afford a satisfactory explanation; and if the rays penetrate through the retina to the choroid, as *Kölliker*, *Draper*, and others believe, it may also explain the phenomenon.

Colour-blindness, or the inability to distinguish certain colours was first observed by *Dalton*, the great chemist, in his own person (hence the name Daltonism, often applied to this defect), and many cases have been since recorded where ludicrous mistakes occurred from the way in which tailors who suffered from it arranged the cloths they were fabricating.

From what has been stated, it will be remembered that for perfect vision the image must be perfectly distinct, must be sufficiently illuminated, and of sufficient magnitude and duration on the retina.

HEARING.

The organ of hearing in man consists of the external ear or pinna and meatus, the middle ear or tympanum, and the internal ear or labyrinth.

The Pinna is composed of a folded sheet of fibro-cartilage, covered with thin skin and a few muscular fibres, often named after the following prominences—the helix or outer rim, the antihelix, which the semilunar fossa divides from the first named, the tragus, and antitragus. The lobe is composed of areolar tissue alone. The attrahens, attollens, and retrahens muscles, and a few ligamentous bands, bind the external ear to the skull. The meatus begins by the hollow, named concha, and leads forwards and inwards, with a slight concavity downwards for about an inch, the lower wall being longer, as the membrana tympani is set at an angle of 45° towards it. About half the canal is made by cartilage, which being deficient above and behind (the fissures of *Sanctorini*), may allow of some alterations in calibre. The entrance of insects or dust is prevented by vibrissæ, and by a sticky secretion, the ear-wax, which, if allowed to harden, is a frequent cause of deafness. The external ear collects and conducts sounds to the membrana tympani, and its remarkably moulded surface fits it to catch vibrations in whatever direction they proceed.

Many animals exceed man in the development of the pinna; and, as is well known, ear-trumpets, or the hand placed behind the ear, will aid its office.

The Middle Ear, or tympanum, is a bony cavity hollowed in the petrous portion of temporal bone, lined by ciliated epithelium, and filled with air, which the Eustachian tube carries up from the pharynx. Its outer wall presents the large opening in which the membrana tympani is set.

This membrane is oval, being rather larger above, and consists of an outer cuticular layer, an inner non-ciliated epithelial layer, and a middle proper layer, composed of strong fibrous tissue, set into a groove in the bone. *Toynbee* describes two such layers, the outer radiating, the inner annular; and *Sir E. Home* described the radiating fibres as muscular. The late *Professor Harrison* dissected that of the elephant, and could not demonstrate its muscularity. He noticed that in this animal there was a perforation, which *Rivinus* regarded as essential. The handle of the malleus is attached to the upper half of the membrane, and, aided by the denser external air, it renders it concave outwards; but in birds it is convex. Examined during life with the speculum, *Sir W. Wilde* compares the membrane to the tint of wet parchment, but rather more pink. Its function in hearing may be shown by the following experiment of *Savart*. He sprinkled fine sand over it, and held a vibrating body near it; it at once vibrated powerfully, and the sand assumed remarkable figures, remaining at what are called "nodal lines" where least vibration occurred.

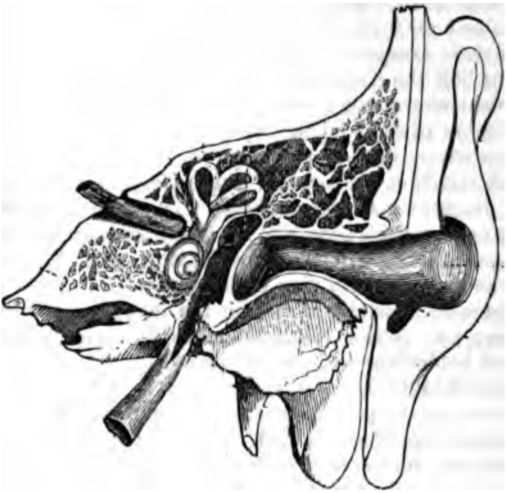


Diagram of the External, Middle, and Internal Ear.

The opposite or inner wall of the tympanum has two openings, the fenestra ovalis leading into the vestibule, and the fenestra rotunda into the cochlea. They are closed also by membranes, and the oval one, which is superior and more than twice as large as the round one, is closed by the base of the stapes. The promontory, caused by the first turn of the cochlea, lies between these openings, and behind them is the pyramid, a hollow funnel of bone, containing the stapedius muscle, which, issuing from the apex, is inserted into the neck of the stapes. Through a hole at the base of the pyramid the corda tympani nerve enters the cavity, and passing between the malleus and incus escapes by a slit in the Glasserian fissure. The aqueduct of *Fallopius*, which carries the facial nerve, slightly raises the bone above the pyramid; and lastly, there are several openings into the mastoid cells which are filled with air.

The anterior part of the cavity has 4 openings: 1. A canal in which the tensor tympani muscle arises, and passes to be inserted into the short process of the malleus. 2. A foramen at the Glasserian fissure, transmitting a ligament misnamed the laxator tympani, which is attached to the processus gracilis of the malleus. 3. The foramen for the exit of the corda tympani; and 4. The Eustachian tube, which leads upwards, backwards, and outwards from the pharynx just behind the inferior spongy bone, where its orifice is large enough to admit the point of the little finger, or the Eustachian sound. It is about 1½ inches long, the lower ⅓ being fibro-cartilaginous, and the remainder a small canal, in the angle between the petrous and squamous portions of temporal bone, parallel to the canal for the tensor tympani, and only divided from it by a thin plate, the processus cochleariformis. This tube is of use in conducting air to support the membrana tympani, in discharging mucus, and in carrying up, it was said, the individual's own voice; but a watch, if placed in the pharynx without touching any solid, is scarcely heard to tick.

The carotid artery and lateral sinus lie close to the tympanum, so that they are endangered in fractures traversing it, and in the ulceration which often follows scarlatina. The late *Professor Porter* saw more blood flow in such a case than he ever saw lost in a surgical operation.

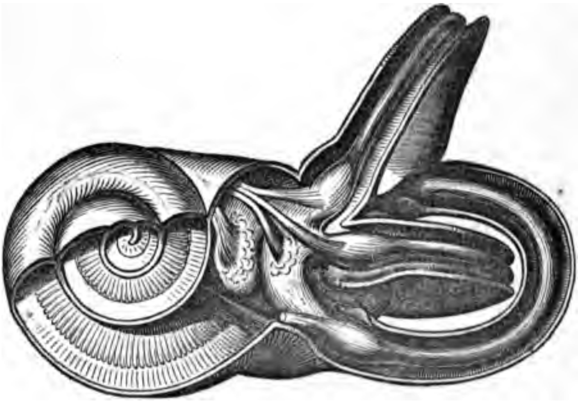
The Ossicula Auditus are from without inwards, the malleus, incus, and stapes. The malleus or hammer consists of a head, neck, and handle, which is attached to the membrana tympani. Its short and long processes give attachment respectively to the tensor and laxator tympani. It articulates by its head and neck with the next bone. The incus or anvil more resembles a molar tooth ; it consists of a body joined to the malleus, a short process running to the mastoid cells, and a long one articulated to the head of the stapes. The end of this process is often an epiphysis, and being detached, is named the "os orbiculare." The stapes is a beautiful little object, precisely like a stirrup, and consists of a head joined to the incus, a neck into which the stapedius is inserted, two branches running to the base, which is set into the fenestra ovalis by a membrane. This bone is the most important, being ossified and nearly of its full size before birth ; and if it be lost, the fluids of the vestibule flow out and complete deafness ensues. The irregular course and free joints of these three bones allow free motion, which is always towards the internal ear, both the muscles producing tension of the membrana tympani. For this reason they have been compared to the iris in function. Even when the muscles are absent, as in the frog, the bones are separate ; but in birds but one bone exists, the columella.

The air in the tympanic cavity insulates or prevents the dispersion of sound from a better conductor, and keeps a due elastic pressure on the membranes, which cannot vary as the temperature is always the same ; echoes are said to be obviated by its free exit through the Eustachian tube. In descending in a diving-bell, or by making a very full exspiratory effort with the nose and mouth closed, the pressure from within is increased, and hearing is rendered very indistinct, distant low sounds not being perceived, though near, and shrill ones are.

The internal ear is named, from its intricacy, the labyrinth, and consists of three parts—the vestibule, semicircular canals, and cochlea.

The Vestibule is a cavity intermediate between the tympanum and the canals and cochlea. Its openings are, the fenestra ovalis, one for the cochlea, five for the semicircular canals, the aqueduct—a small venous passage lined by dura mater, and several minute perforations (the macula cribrosa), through which the auditory nerve enters from the internal meatus.

The Semicircular Canals each form more than half a circle, and are a little flattened laterally, and about $\frac{1}{20}$ in width. They open into the vestibule by each end; but two of them, the superior and inferior, previously joining, only 5 openings exist. One end, more dilated



The Labyrinth—Vestibule, Semicircular Canals, and Cochlea—the bony and membraneous portions of the first and second being displayed.

than the other, is named the ampulla. The superior canal is anterior to the others, and rises so high as to raise the upper surface of the petrous portion, or to project free from it in the fœtus. The inferior canal is behind and at right angels to the last, and the horizontal leads backwards and outwards, and is the shortest.

The two parts of the osseous labyrinth we have now described are lined by the membraneous labyrinth. This is much smaller—but ⅓ in the canals, as a fluid, the perilymph or liquor Cotunnii, intervenes, save where the nerves enter. Another fluid, the endolymph, discovered by *Scarpa*, fills the membraneous labyrinth, and being nearly incompressible, carries impressions from the fenestræ. Deafness follows its escapes by puncture. Three coats constitute the membrane—an outer, soft and stained by pigment cells, almost identical with those of the choroid; a middle, tough and transparent-like fibro-cartilage; and an inner, consisting of nucleated epithelium. The acoustic artery forms a plexus, very like that of the retina, on the outer surface. Particles of carbonate of lime are always found in the endolymph, consolidated into earstones or otoliths in fishes, and an ear-dust or otoconia in other animals. In man the particles are not loose in the fluid, but bound in masses by some delicate tissue.

The Cochlea, so named from its likeness to a shell, is an astonishing complex apparatus. It is conical, with its base towards the internal meatus, from which it proceeds forwards and outwards, almost horizontally. An axis, or modiolus, runs up the centre from base to apex, and round this is wound, for 2½ turns, the spiral canal, about 1½ inches in length, and $\frac{1}{10}$ in width. There are 3 openings at the beginning of the canal—one into the vestibule; another, closed by membrane, into the tympanum—the fenestra rotunda; and the aqueduct, which carries a vein to the jugular fossa. The canal is divided by the spiral lamina into two passages—a superior, the scala vestibuli, communicating with the vestibule; and the scala tympani, which begins at the fenestra rotunda. The spiral lamina consists of bone towards the modiolus, then of a membrane like the capsule of the lens; a large capillary runs along its under surface; and, lastly, of a structure which *Kölliker* describes as the spiral ligament, but which *Bowman* named the cochlearis muscle. In tissue it is very similar to the ciliary muscle, and as it can make tense the spiral lamina, its function may be analogous. On the upper surface of the bony part of the lamina, *Bowman* discovered a beautiful structure, which, from having a toothed edge, he calls the denticulate lamina. Its texture is like cartilage, with cells remarkably arranged. Its teeth project into the scala vestibuli, and in a groove below them are found columnar cells, not unlike those of *Jacob's* membrane. Below the membraneous part the *Marquis Corti* discovered another layer, and the space between them may be called the scala media. The bony lamina ends above by a hook or hamula, the concavity of which is named the helicotrema, as the scalæ communicate through it. The spiral canal dilates into a summit-like dome, the cupola, which the modiolus includes somewhat by spreading into an infundibulum.

The Auditory Nerve, or portio mollis of 7th, arises in the medulla oblongata by fibres at the back of the calamus scriptorius. In its softness and absence of neurilemma it resembles the brain substance more than nerves, and it contains many bipolar cells. A ganglion, very distinct in the carp, is found at its origin, and some regard the pneumogastric lobule in this light. Together with the facial nerve and some other fibres which *Wrisberg* named the portio intermedia, it enters the internal meatus and divides into one portion for the vestibule and semicircular canals, and another which becomes the cochlear nerve. The vestibular nerves tie closely together the osseous and membraneous surfaces, and some seem to end by running towards the otoconia, others by spreading out on the inner side of the membrane, having lost their white substance. In the semicircular canals the nerves only extend as far as the ampullæ, where they end in a forked or looped manner. The cochlear nerve passes up through the modiolus and sends branches to the under surface of the spiral lamina, where they form a most intricate plexus.

The Laws of Sound are epitomised as follows, by *Todd* and *Bowman*, in their admirable article on the organ of hearing:

"The following points respecting the laws of sound should be borne in mind in considering the offices of the various parts of that complex acoustic apparatus, the human ear:

"1. Any irregular impulse communicated to the air will produce a *noise;* a succession of impulses occurring at exactly equal intervals of time, and exactly similar in duration and intensity, constitute a *musical sound.*

"2. The frequency of repetition necessary for the production of a continued sound from single impulses is, probably, generally not less than sixteen times in a second; but *Savart* thinks that some ears may distinguish a sound resulting from only ten or eight vibrations in a second. On the other hand, sounds are audible which consist of 24,000 vibrations in a second.

"3. Sound may be propagated or conducted by air, gases, liquids, and solids, with various degrees of rapidity.

"4. Sound travels through air at the temperature of 62° Fahr. at the rate of 1,125 feet in a second.

"5. Sound is incapable of transmission through a vacuum.

"6. The propagation of sound is the more effectively performed as the medium of transmission is more dense. Rarefied air, gases of low density, and soft solids, are less perfect conductors of sound than much denser materials of the same kind.

"7. We distinguish in sounds—1, the pitch; 2, the intensity or loudness; 3, the quality or timbre.

"The pitch of the sound depends on the rapidity with which the vibrations succeed each other; and any two sounds produced by the same number of vibrations or impulses in the same time, are said to be in unison.

"The loudness or intensity depends upon the violence and extent of the primitive impulse.

"The quality is supposed by *Herschel* to depend on the greater or less abruptness of the impulses, or generally on the law which regulates the excursions of the molecules originally set in motion.

"8. The velocity with which sound travels is, however, quite independent of its intensity or of its tone; sounds of every pitch and of every quality travel with the same speed through the same medium, as is proved by the fact that distance does not destroy the harmony of a rapid piece of music played by a band.

"9. Water propagates sound with much greater velocity than air does. *Colladon* concludes from numerous observations that the velocity of sound in water, at 40° Fahr., was at the rate of 4,708 feet in a second.

"10. According to *Biot*, cast-iron propagates sound at the rate of 11,090 feet in a second.

"11. Sonorous undulations, in passing from one medium to another, always experience a partial reflection, and when they encounter a fixed obstacle, they are almost wholly reflected. The reflection of sound occurs according to the same law which regulates the reflection of light—namely, the angle of reflection is equal to the angle of incidence.

"12. The phenomena of echoes result from the reflection of sound from any prominent object."

The vibrations carried to the labyrinth by the chain of bones and the air in the tympanum will more readily affect the vestibule, and those by the bones of the head, the cochlea. *Dugès* suggested that the special use of the cochlea was to estimate the pitch of sound and of voice, as in animals it bears ratio to the development of vocal organs. The semicircular canals hold the same relative position in all animals, and this fact suggested to *Wheatstone* and others that they are the means by which we determine the direction whence sound issues. *Flourens* asserts that injury to them will cause animals to move in various directions, according to the canal perforated. The calcareous particles in the endolymph must increase the intensity of vibration to the membraneous labyrinth, as when a stone is placed in a bladder of water, any impulse is most distinctly felt by the hand holding it. *Dr. Wollaston* calculated the range of human hearing as 9 octaves, the lowest notes of the organ and the cry of some insects being the extremes. That sounds leave a sensation after they have ceased, *Savart* proved by removing one tooth from a toothed wheel, when no interference with the sound could be detected. Tinnitus aurium, the noise of flowing water, &c., are subjective sensations which are often indicative of cerebral disease. The following interesting parallel between the ear and eye is drawn by *Wharton Jones:*

"The comparison which I should institute between the component parts of the ear and the eye is the following:

"The osseous labyrinth may be compared to the sclerotica; and the fenestra rotunda, or cochlear fenestra, to the cornea.

"To find a part in the eye analogous to the vestibular fenestra, we must first consider that the latter is a yielding part of the otherwise solid wall of the labyrinth; that, through the medium of it, the chain of small bones and their muscles in the tympanum exercise on the soft parts contained in the labyrinthic cavity a certain degree of tension or compression, fitted propably to accommodate in some manner the ear to the perception of different degrees of sound. In the case of the eye, the sclerotica, which corresponds to the osseous labyrinth, is thinner and more yielding at the middle of its circumference (remarkably so in the Greenland seal). From this it has been supposed that the action of the muscles of the eye-ball might, by their compression, produce a change of shape fitted to accommodate the eye to distances. Hence the vestibular fenestra and middle thin part of the sclerotica might be compared to each other, in as far as regards the function which each performs in the economy of its own organ. However this may be, the vestibular fenestra of the ear and the thin part of the sclerotica correspond to each other as far as can be in relative position; and, if we admit the action just mentioned of the muscles upon the eye-ball, we have, as I shall immediately show, their counterparts in the muscles of the small bones of the tympanum.

"The tympanic scala of the cochlea may be compared to the anterior chamber of the aqueous humour, and the vestibular scala to the posterior chamber.

"The spiral lamina, considering its vascularity and richness in nerves, and its forming a partition between two chambers containing an aqueous humour, may, as I have already said in a former part of this article, be considered the counterpart of the iris, and the helicotrema, that of the pupil.

"The membrane lining the labyrinthic cavity bears the same relation to the latter as the arachnoidea oculi does to the sclerotica. The place filled with perilymph, between the osseous and membraneous labyrinth, may be considered analogous to that between the sclerotica and choroïd. It however communicates with the scalæ of the cochlea, the parts analogous to the chambers of the aqueous humour, because there is nothing in the ear to be compared to the ciliary ligament.

"Forming the membraneous labyrinth we find: 1, a delicate cellular tissue supporting the branches of the blood-vessels, and which is sometimes found containing black pigment; 2, a firm, transparent, membraneous coat, within which, 3, is a nervous expansion; 4, the endolymph; 5, suspended in the latter the mass of calcareous matter. The cellulo-vascular layer containing pigment, together with the rest of the walls of the membraneous labyrinth, may be compared to the choroid coat of the eye, the nervous expansion to the retina, the endolymph to the vitreous humour, and the calcareous mass to the lens.

"In the lower animals the cochlea is the first part of the ear-bulb to disappear; in regard to the eye-ball, the aqueous chambers, to which I have compared the scalæ of the cochlea, are, in like manner, the first parts which, in the depreciation of the structure of the eye, in the animals series, disappear; *e.g.*, the eye of the Cephalopodous Mollusca.

"Is the cochlear nerve the same in function with the vestibular? The vestibular nerve is the special nerve of hearing; but does not the cochlear nerve perform some function in the economy of the ear analogous to what the ciliary nerves perform in that of the eye?

"If an example is required in which the optic nervous filaments enter the eye separately, as do the nervous filaments of the ear-bulb, it is to be found in the Cephalopodous Mollusca.

"As in front of the eye-ball there is—or rather would be if it was not that the eyelids are constantly in contact with the eye-ball—a space lined by a mucous membrane, the conjunctiva; so, at the peripheral surface of the ear-bulb there is a space—the tympanic cavity—lined by a mucous membrane also. Moreover, as there is a passage into the nose from the space bounded by the conjunctiva, so does the tympanic cavity communicate with the throat by the Eustachian tube. In the tympanic cavity there is a chain of small bones, articulated to each other and moved by muscles, which serves to produce some change in the state of tension of the soft parts of the ear-bulb; in the conjunctival space there is nothing analogous—although, without pushing the point too far, we might compare the muscles of the eye-ball with those of the ossicles of the tympanum, both being equally, in fact, outside their respective mucous membranes. In regard to the ossicles, I would remark that, according to the views of *Weber*, they must be reckoned among those which do not belong to the skeleton, and which are of very inconstant occurrence. Such are the bone of the penis in many animals, the teeth, the ring of bony plates round the front of the sclerotica of the bird's eye, &c.

"A part in the composition of the appendages of the eye analogous to the membrana tympani is only to be conceived by supposing the existence of a mediate anchyloblepharon—that is, an irregular membrane stretched between the edges of the eyelids, uniting them together and closing in the space lined by the conjunctiva, which space would now communicate with the exterior only by the lachrymal canalicules and nasal duct, in the same way that the tympanic cavity communicates with the exterior only by the Eustachian tube. A congenital fissure, or total absence of the membrana tympani, is an irregularity of structure in the ear which may be compared to what is regular in the eye. A mind accustomed to trace analogies will perceive a resemblance—to the external auditory passage in that short space at the opening of the eyelids, extending from the inner edge of the tarsal margin to the outer; to the ceruminous glands in the Meibomian follicles; and to the hairs at the entrance of the auditory passage in the eyelashes. The auricle, if it is necessary to look for a part corresponding to it, may be placed in the same category with the eyebrows."

FACIAL, PNEUMOGASTRIC, AND ACCESSORY NERVES.

The Facial nerve is traceable from the olivary column to a space bounded by the pons, olivary body, and pneumogastric lobule, where it lies close to, but above the portio mollis. After traversing the internal meatus, it passes through the Fallopian aqueduct, in which it is joined by the lesser petrosal nerve from the otic ganglion, and the greater petrosal, or vidian, from *Meckel's* ganglion. Where the latter nerve strikes it, a swelling—the intumescentia ganglioformis—is found, from which the corda tympani arises; and beyond this it supplies the stapedius and tensor tympani, and emerges through the stylomastoid foramen. In the parotid it sends off auricular stylohyoid, digastric, cervico-facial, and temporo-facial branches, the latter forming the pes anserina, which supplies all the superficial muscles of the face. Its distribution in man and other animals, and the effects of division or disease, clearly demonstrate its function to be purely motor. It is the nerve of facial expression, and varies in animals in size according to the amount of this power. It supplies the muscles of the soft palate by a branch sent back along the vidian nerve. Its branch, the corda tympani, supplies the lingualis muscle. Its function is beautifully indicated by that common affection termed *Bell's* palsy, in which this nerve is alone affected. When the cause is intracranial, the eye remains open, the tears overflow, the brow and face are unwrinkled and expressionless, the cheek puffs, and the air escapes through the corner of the mouth if the patient tries to whistle; the ala nasi is loose, deafness happens, and, in some way, taste is impaired—so that four of the organs of special sense are affected. The patient's utterance is also often imperfect, from the injury to the lingualis and palatine branches. The sketch of the anatomical distribution of the nerve we have given above, explains all these symptoms.

The Accessory nerve is quite peculiar in origin, as it takes root, by 6 or 8 filaments between the anterior and posterior roots, along the side of the spinal cord, as low as the 5th cervical nerve. Passing up through the foramen magnum, it again leaves the cranium by the jugular foramen, sends a large branch to the pneumogastric, pierces the sterno-mastoid, and supplies the trapezius. Experiments have afforded very clear proof that the branch it sends to the vagus is motor, and is mainly sent to the larynx, to which it goes directly in quadrumana. The sterno-mastoid and trapezius are also supplied by the cervical plexus. *Sir C. Bell* regarded the accessory as a respiratory nerve.

The Pneumogastric, which is the most extensively connected of all nerves, arises in the groove between the olivary and restiform bodies, and escapes by the jugular foramen. Below this it forms a swelling often termed the laryngeal ganglion of *Sir A. Cooper*, and in passing over the subclavian artery swells into the plexus gangliofórmis of *Vieussens*. Its course in the neck, thorax, and abdomen forms an important anatomical study, and is depicted on page 291. Its main branches are: 1. Communicating; 2. Pharyngeal, motor to the muscles of pharynx; 3. Superior laryngeal, sensitive to mucous surface, and a twig to the crico-thyroid, which can be traced back to the accessory; 4. Cardiac, which join the cardiac plexus; 5. Inferior or recurrent laryngeal, so called from winding round the subclavian on right side, and the arch of the aorta on the left. *Mr. Hart*, late Professor of Anatomy in our College, has explained this course by the relations of the brain and larynx to the great vessels in early life. In birds it passes direct to the lower or vocal larynx. This nerve supplies all the laryngeal muscles, save the crico thyroid, and, according to *Reid*, sends sensitive filaments to the trachea. 6. Pulmonary branches, forming the anterior and posterior pulmonary plexuses. 7. Œsophageal, which form the plexus gulæ. 8. Gastric branches, which can be traced into the submucous or nervous coat of the stomach.

Most numerous experiments have been performed on the pneumogastric nerve. Irritation produces vermicular motion of the stomach. When they are divided, loathing of food is at first observed, but the animals afterwards eat without the feeling of satiety; gastric juice is still poured out and digestion proceeds. *Brodie* stated that after section of these nerves no mucus was poured out, so that arsenic killed more rapidly and the coats of the organ were themselves digested—but such results cannot always be obtained. When divided in a rabbit above the œsophagus, the animal eats so voraciously that the food accumulates in the stomach, œsophagus, and air-passages. The cardiac filaments seem to have a common action with the sympathetic on the heart. Section of one nerve does not materially affect respiration; but if both are divided above the lungs the animal dies in about 3 days, unless the ends are kept close together, when they survive 12. The animal suffers from dyspnœa, the "besoin de respirer" still existing, and after death the lungs are found congested and engorged with a serous fluid, due partly to the inflammation which foreign bodies produce by entering the air passages. If the superior laryngeal nerve is divided, irritants produce no effect on the glottis, which before was exquisitely sensitive. Irritation of the inferior laryngeal produces spasm of all the muscles save crico-thyroid; and division of it produces paralysis of them followed by death, as the arytenoid cartilages fall together—the apnœa occurring more rapidly in young animals on account of the cartilages being more movable. *Magendie* regarded the superior as the constrictor, and the inferior as the dilator nerve of the organ; and thus accounted for death by the unopposed action of the former when disease or injury destroyed the latter. Partial or complete aphonia is another effect of injury to the recurrent nerve. Many diseases, such as spasm of the glottis, hooping-cough, stomach-cough, &c., are due to reflex action of this great trunk by irritation of some of its branches.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Describe the structure and uses of the upper eyelid. Is there any rudiment of a third eyelid?
2. Explain the action of the agents by which we produce dilatation and contraction of the pupil.
3. What is the form of the human eye? Describe the coats which preserve its form permanently.
4. What is the structure and use of the inner coat of the choroid?
5. Enumerate the dioptric media.
6. Describe the structure of the optic commissure and nerve.
7. Give a short sketch of the nature, components, and properties of light, and explain what is meant by complementary colours.
8. Sketch the physiological purpose of each part of the external ear.
9. Enumerate the openings in the tympanum, and describe the structures which fill the largest of them.
10. Describe briefly the labyrinth and the structures which fill the semicircular canals.
11. What is the function of the facial nerve, and how has it been proven?
12. Mention the results which follow section of the pneumogastric opposite the following points: 4th cervical, 3rd and 8th dorsal vertebræ.

SENIOR.

1. Explain the movements of the eyeball, and the arrangements of the orbit to permit them.
2. Describe the tunica vaginalis oculi of *O'Ferrall*, and the practical deductions which follow from its study.
3. What are the symptoms of disease of the oculo-motor nerve?
4. Describe the layers of the cornea and the changes they undergo in staphyloma.
5. What means are there for regulating the amount of light admitted to the retina?
6. Sketch the structure of the various layers of the retina, particularising any appearances presented by it posteriorly.
7. What is *Prof. Hayden's* view of the function of the yellow spot?
8. Relate what happens to a ray of light as it passes through the eye.

9. What powers render the eye superior to any artificial combination of lenses, and what are its most common optical defects?
10. How are the vibrations carried from the membrana tympani to the fenestra ovalis, and how can the tensity of the chain be regulated?
11. Describe the spiral lamina, and say what functions have been assigned to each part of the internal ear.
12. State a few analogous parts in the eye and ear.

REPRODUCTION.

The multiplication of individuals is accomplished in the vegetable and animal kingdoms in a great variety of ways, but in all cases the presence of a protoplast, or pair of protoplasts, is essential. The old doctrine of spontaneous generation was mainly supported by the production of infusoria and other minute organisms in places where no germ could be discovered, but the progress of microscopical science, as well as the following experiment of *Schultze*, has overthrown the hypothesis. This naturalist found that infusions of organic matter, if exposed to the influence of the air, warmth, and light, soon swarmed with living beings; but if he compelled the air to traverse sulphuric acid or solution of caustic potash, all germs were destroyed, and at the end of 3 months the infusions were free from all trace of animalcules. As we proceed we shall have further proof of the aphorism, "omne vivum ex ovo," for which the immortal *Harvey* so perseveringly contended. He asserted that "all animals—whether they be swimming, walking, or flying animals, and whether they be born in the form of an animal or of an egge—are all generated after the same manner." The numerous modes of reproduction are tabulated as follows by *Prof. A. Thomson.* I have added an example of each form:

- Non-sexual.
  - Fissiparous.
    - Parent splits, each part a new animal.
      1. Transverse—*Amœba.*
      2. Longitudinal—*Vorticella.*
      3. Irregular—*Gonium.*
    - Parent splits and discharges the young.—*Volvox.*
  - Gemmiparous.
    - Budding upon the parent stock—*Hydra.*
    - Separated buds. Gemmæ or sporules.
      1. On all parts of the body—*Medusa.*
      2. On one part or organ only—*Tunicata.*
- Sexual.
  - Hermaphrodite. Both sexual organs on one individual.
    1. Self-impregnation—*Tapeworm.*
    2. Mutual impregnation—*Snail.*
  - Diœcious.
    - Oviparious, laying eggs which are hatched.
      1. External fecundation—*Herring.*
      2. Internal fecundation—*Fowl.*
    - Ovo-viviparous. Eggs hatched within the maternal body—*Snake.*
    - Mammiferous, suckling the young.
      1. Monotrematous—*Ornithorynchus.*
      2. Marsupial—*Kangaroo.*
      3. Placental or strictly viviparous—*Man.*

The ovum, which results from the higher of these processes, may undergo several important changes before it exactly resembles its parent or parents, and such changes are termed metamorphoses. This phenomenon is well illustrated in the insect world—for instance, the ovum which the butterfly produces develops at first into a larva (caterpillar), which next appears as the chrysalis, from which the fully formed insect arises, and bears an exact resemblance to the parent.

Alternation of Generations was the termed applied by *Steenstrup* to a remarkable phenomenon, by which the larval or imperfect form gives rise to a creature which eventually comes to resemble the animal, its grand-parent, which produced the original ovum. As the least complex example, I select the common tape-worm to illustrate this wonderful phenomena. The ova of the tape-worm, if introduced into the body of the pig, therein produce the entozoon known as cysticercus cellulosæ, which, if present in great quantity, gives rise to that condition of its flesh termed "measly." If such meat be partaken of, especially if underdone, these creatures develop into that formidable parasite the tænia solium. These facts have been ascertained in numerous carefully conducted experiments on a criminal, who, in consideration of a short reprieve, allowed the cysticerci to be introduced into his body.

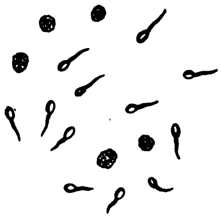
Parthenogenesis, or virgin reproduction, is the term which *Prof. Owen* uses to designate the remarkable process by which part of the germ-mass produced in one generative act is transmitted through the successive broods which arise. The aphis, or blight insect, is an example of this kind, one impregnation being enough to produce many generations (20 according to *Prof. Huxley*), when a fresh one is required.

Brief as this sketch is, it is necessary to allude to the remarkable theory of *Darwin*, which has, within the last few years, created so intense an interest. In his work "On the Origin of Species by means of Natural Selection, or the preservation of favoured races in the struggle for life," this naturalist supposes that there exists in nature powers, acting very slowly but surely, capable of producing new species by gradual modification and without the special exercise of creative effort. That, for instance in epochs long past, there existed a fish which has been the common ancestor of the herring, sardine, sprat, &c., secondary causes and not the direct interposition of Providence, having perfectly adapted each species to the precise position it fills in the universe. Again he says: "I believe that animals have descended from at most only four or five progenitors, and plants from an equal or lesser number. Analogy would lead me one step further—namely, to the belief that all animals and plants have descended from some one prototype. But analogy may be a deceitful guide. Nevertheless all living things have much in common in their chemical composition, their germinal vesicles, their cellular structure, and their laws of growth and reproduction. We see this even in so trifling a circumstance as that the same poison often similarly affects plants and animals ; or, that the poison secreted by the gall-fly produces monstrous growths on the wild rose or oak-tree. Therefore, I should infer from analogy that probably all the organic beings which have ever lived on this earth have descended from some one primordial form, into which life was breathed by the Creator." In the struggle for life and by the numerous variations which occur, less-improved forms become extinct, and " thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life with its several powers having been originally breathed by the Creator into a few forms, or into one ; and that whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning, endless forms, most beautiful and most wonderful, have been and are being evolved."

THE MALE GENERATIVE ORGANS

Include the testis and its duct, the vesicula seminalis, the prostate, urethra, and penis ; and we shall very briefly describe their structural anatomy.

The Testis is a gland composed of about 800 minute tubes, the tubuli seminiferi, about $\frac{1}{180}$ in diameter, and from 13 to 33 inches long. They are rolled into about 300 packets, from which about 15 tubuli recti emerge to form the rete testis in the layers of the mediastinum. From the body of the gland about 10 vasa efferentia lead, and form the epididymus—a convoluted tube about 21 feet long ; and it is calculated that the whole seminal tubing measures over $\frac{3}{4}$ of a mile. The tubules have a fibrous coat and an epithelial lining, and during the activity of the gland are filled with cells in which the spermatozoa become developed as spiral threads and gradually matured as they reach the vas deferens. Sem as it is ejaculated consists of the combined secretions of the testis, seminal vesicle, prostate, and some smaller glands, and is a whitish tenacious fluid with a peculiar smell. It liquifies on exposure to air. It contains albumen, a peculiar principle, spermatin, and phosphates, which often crystallize.

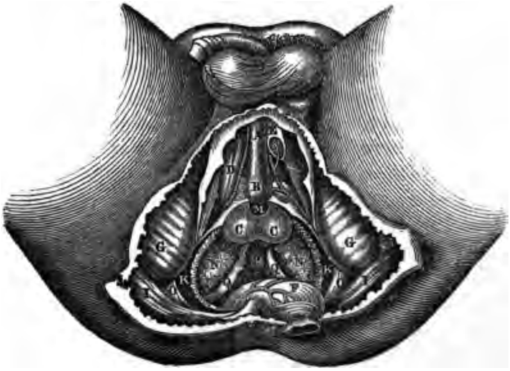


Spermatozoa and Seminal Cells.

The microscope discovers in it peculiar bodies, the spermatozoa—and those of man are here represented. The identification of semen in linen stains is often of judicial importance in cases of rape. Including the head and tail, they are about $\frac{1}{600}$ in length, and by the movement of the tail are propelled forward at the rate of 1 inch in 7½ minutes. Water increases such movements at first, but they then become indistinct by osmose. Urine, strychnia, opium, hydrocyanic acid, and electric currents stop the movements, which continue longer in the organs of the female than in any other situation. They have been seen to move in the female organs of insects for many months. In semen that has been dried the movements may be restored by solutions of alkalies, albumen, sugar, &c. They contain lime, and thus it is stated that they may be heated to redness without losing their peculiar form. Spermatozoa, as the name implies, were long considered as animalcules—indeed *Lewenhoeck* called them "homunculi;" but physiologists now regard them as gland-cells with a single cilium attached, their motion being due to osmotic currents. That they are necessary for fecundation is shown by their absence from the semen of immature or hybrid animals, and *Newport's* experiment of filtering them from the semen of insects. They enter into the interior of the ovum by an opening named the micropyle, which *Ransom* has discovered in fishes; but it has not been ascertained positively to exist in other vertebrates.

We are in complete ignorance of the manner in which the fœtus, through the influence of this fluid, partakes of the features, physical and mental characteristics, and proclivity to disease of the father; and still less can it be explained how mares and other female animals will bear offspring partaking of the character of a male by which she had been long before impregnated.

The semen is conducted by the vas deferens—a tortuous tube abounding in muscular tissue—to the prostate where, joining the duct of the seminal vesicle, it forms the common ejaculatory duct. •



Male Generative Organs.

A. Corpus Spongiosum Urethræ. B. The Bulb. CC. The two lateral Lobes of the prostate. D. The right Erector Penis Muscle. E. The left Crus Penis divided so as to show the Artery of the Corpus Cavernosum. F. The Rectum turned down. GG. The Tuberosities of Ischia. II. The great Glutæi Muscles. KK. The Levatores Ani Muscles divided and partly removed. M. The membraneous portion of Urethra. NN. The Vesiculæ Seminales. OO. The Great Sciatic Ligament. P. The base of the Bladder. QQ. The two Vasa Deferentia becoming tortuous before their termination.

The Seminal Vesicle consists of a cœeal tube, much convoluted, and lined by a fine honeycomb mucous coat, exactly like that of the gall-bladder. Whether these organs merely lodge the semen, secrete an independent fluid, or both, is undetermined. They often contain spermatozoa, which may have merely moved back from the vas deferens. They are absent in many animals, do not waste after castration, and in the elephant there are seminal reservoirs distinct from them.

The Prostate consists of many ducts opening into the urethra and pouring out viscid mucus, and is chiefly made up of a mingled fibrous and muscular substance, very similar to that of the uterus. The following glands also pour mucus into the urethra—the sinus pocularis, which *Weber* termed the uterus masculinus, the antiprostatic glands of *Cowper*, lacunæ, and some branched follicles called the glands of *Littre*. The urethra, the common urino-genital passage, has been before alluded to. Its posterior curve is equal to $\frac{3}{10}$ of a circle $3\frac{1}{4}$ inches in diameter, which is therefore the proper curve for catheters. The spongy body which surrounds it, dilating into the bulb behind, and the glans penis in front, are represented in the foregoing view of the male organs from the perineum.

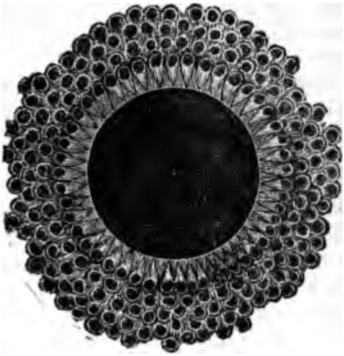
*Helicine Arteries ending in smaller vessels.**

The Penis is mainly composed of erectile tissue, which has been described at page 147, but, according to *Müller*, there are peculiar arteries he termed helicine, from their shell-like curves. He believed these were cœcal, and that they only contained blood during erection. *Kölliker* has found that they are not exactly cœcal, but that extremely fine vessels lead from them. *Houston* believed that the erect state of the organ was due to compression of the dorsal vein by a few fibres of the ejaculator seminis, which he called the "compressor venæ dorsalis penis."

Puberty occurs in man about the 14th or 15th year, and is marked by the development of sexual feelings, enlargement of the genitals, and the presence of spermatozoa in the semen. Among other concomitant changes are the growth of hair on the face and pubis, increase in size of the thorax and larynx, producing deeper vocal tones, masculine strength, symmetry, and physiognomy, and greater courage and other mental endowments. Such changes do not occur when the testis are undeveloped or abstracted, as in eunuchs. Procreative capacity lasts till beyond 60, or in many recorded cases much longer.

THE FEMALE GENERATIVE ORGANS

Are the ovary, Fallopian tube, uterus, and external organs.



The Ovum, Zona, Pellucida, and Cells of the Germinal Disc.

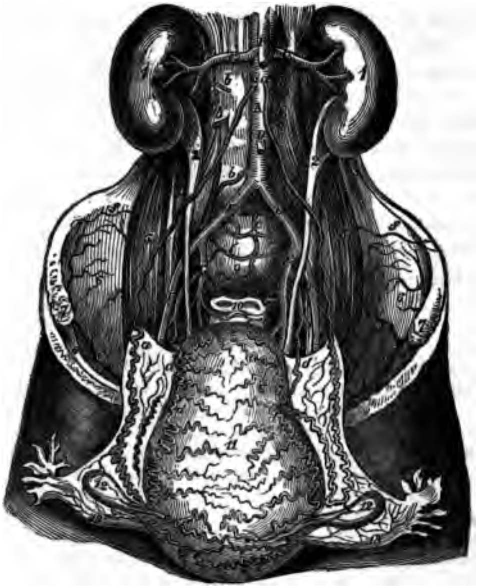
The Ovary is an oval gland, tied by a fold of peritoneum and an impervious ligament to the uterus. It consists of a fibrous coat, the tunica albuginea, like that of the testis, and a fibro-vascular stroma, in which are imbedded the Graafian vesicles, varying in number from 10 to 50, and in size from that of a pin's head to that of a pea. Each vesicle or ovi-sac consists of a cell wall, lined by a hyaline basement layer and a thick epithelium, termed the membrana granulosa. The ovum is fixed in this epithelium by retinacula, according to *Barry*, and the rest of the vesicle in filled with fluid.

The Ovum is a circular body about $\frac{1}{120}$ in diameter, covered by a clear coat exactly similar to the elastic layers of the cornea, and termed the zona pellucida or yolk membrane. This encloses the yolk, a semi-fluid mass of granules and oil particles, and near its circumference the germinal vesicle of *Purkinje*, within which is lastly to be perceived the germinal spot. The yolk granules and ovum of the rabbit during rut are figured on the foregoing page.

The Fallopian Tube, or oviduct, begins by a fimbriated extremity, at which the peritoneal sac is open during conception, and terminates at the upper angle of the uterus. It has a strong fibro-muscular coat and a ciliated mucous surface, the movements of which are towards the uterus.

The Uterus is of a flattened pear shape, consisting of a fundus, at the angles of which the Fallopian tubes enter, a body and a cervix projecting into the vagina, and across which there is a slit-like opening—the os uteri. The cavity of the womb is very narrow and contains but a little mucus. Its wall is about ½ an inch thick, and consists of muscle-cells and fibres running in every direction irregularly—save round the os, where they make a partial sphincter. Within the cervix are the glandulæ *Nabothi*, which secrete a plug of viscid mucus. The uterine nerves are derived from the sacral and hypogastric plexuses, and from many ganglia, according to *Lee*, in the impregnated organ. The uterus is said to have increased 24 times in size at the end of pregnancy. Its arteries, after this state had terminated, but before they had undergone much reduction, are here represented. The external organs are described in the anatomical treatises of *Harrison*, *Ledwich*, *Gray*, &c.

Menstruation is the occurrence which usually marks the aptitude for impregnation—but a few cases are recorded where females became pregnant although the catamenia never appeared. Between the 14th and 16th year is the usual period for their commencement in this country; but in hot climates, and in girls of luxurious, idle habits, they have appeared much earlier. Greater obesity, enlargement of the mammæ and genitals, and the development of sexual passion mark the period. Menstruation occupies about 4 days, returns every month, and ceases with procreative power about the 50th year, when what is termed the "change of life" occurs. Menstrual blood, if obtained from the uterus, differs but little from



The Vessels of the Uterus six days after delivery.

ordinary blood; but if mixed with the vaginal fluids, is acid, dark coloured, and fluid. About 6 ounces are poured out, but no fibrin is usually present.

The analogy of menstruation with "heat" in animals has been completely demonstrated of late years; but *Cruikshank*, in 1797, ascertained that an ovum was discharged with the menstrual fluid. Shortly after the occurrence, sexual desires are increased, and impregnation is much more apt to occur. The catamenia cease during pregnancy and lactation, and occur at very irregular periods in many females who are sterile. Each discharge of an ovum leaves a cicatrix upon the ovary, which is termed the "false corpus luteum," that which is known as "true" occurring in pregnancy. They are thus contrasted by *Dalton:*

	Corpus Luteum of Menstruation.	Corpus Luteum of Pregnancy.
At the end of three weeks,	Three-quarters of an inch in diameter; central clot reddish; convoluted wall pale.	
One month,	Smaller; convoluted wall bright yellow; clot still reddish.	Larger; convoluted wall bright yellow; clot still reddish.
Two months,	Reduced to the condition of an insignificant cicatrix.	Seven-eighths of an inch in diameter; convoluted wall bright yellow; clot perfectly decolorized.
Six months,	Absent.	Still as large; clot fibrinous; convoluted wall paler.
Nine months,	Absent.	One-half an inch in diameter; central clot converted into a radiating cicatrix; wall without yellow colour.

The existence, however, of hematoidin crystals, or of fatty matter to which the yellow colour is due, affords evidence of the corpora lutea for a much longer period.

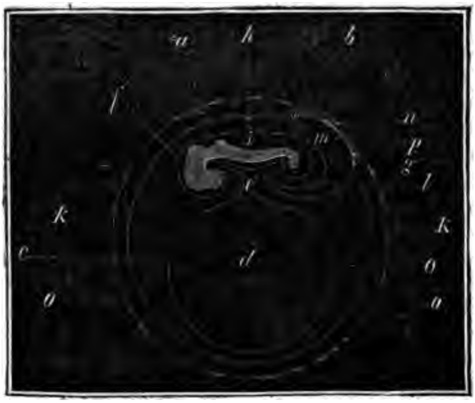
THE IMPREGNATED OVUM.

The changes which the ovum undergoes after impregnation have been necessarily examined only in the lower animals. The time which elapses between impregnation and the escape of the ovum into the Fallopian tube varies much, being sometimes but a few hours, and in the deer being four months, according to *Pockels.* The cells of the membrana granulosa become club-shaped and radiated round the ovum as it leaves the ovary, and disappears as it enters the uterus. While passing through the Fallopian tube the ovum enlarges, loses its vitelline membrane, and gets a covering from the mucous surface which is developed into the chorion.

The yolk undergoes remarkable rotation by means of cilia, and then becomes divided by dichotomous cleavage into many cell-like bodies with a light centre. After this segmentation, and about the time the ovum enters the uterus, the germinal membrane, or blasdodermic vesicle of *Bischoff,* forms within the zona pellucida.—From the surface of this membrane, at a spot termed the "area germinitiva," the embryo becomes developed—the nervous system and organs of animal life from its outer surface, and the digestive and other vegetative organs from its inner. These two surfaces are called respectively the serous layer and the mucous layer.

The Decidua is meanwhile forming in the uterus by an alteration in its tissue, as *Sharpey* believes, assuming a soft, thick, and vascular condition. Into this the ovum and its chorion become firmly set. On its surface are many openings of tubular glands which dip into the uterine wall, and which receive the tufts of the chorion. Tho ovum becomes covered by the "decidua reflexa," which *Hunter* described as pushed before the ovum as it left the Fallopian tube, the mouth of which he stated was subsequently closed by the "decidua serotina." If the decidua be an altered state of the mucous membrane of the uterus, this view cannot be correct. Both decidua vera and reflexa incorporate about the 3rd month, and are expelled at parturition.

The tufts of the chorion next accumulate at the side of the ovum next the decidua vera, and here form the placenta, by which the human fœtus and that of other placentalia derive blood in the later months of utero-gestation. According to *Goodsir*, the following structures separate the maternal and fœtal blood—the wall of the venous sinus, a thin layer of decidua, a stratum of fluid, the cells and membrane at the end of the tufts, and the walls of the fœtal capillaries.

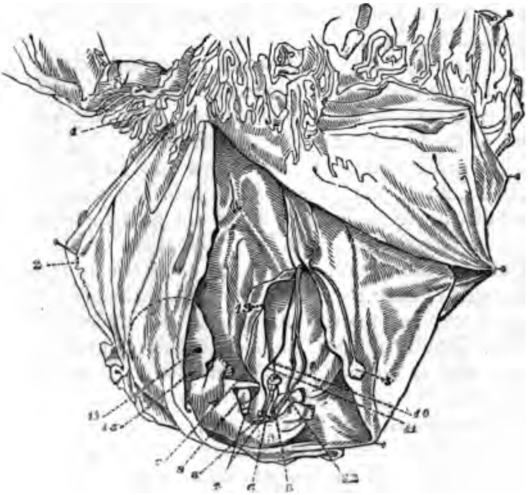


The Embryo and its Coverings.

a, b. Embryo. c. Vitelline membrane. d. Yolk. e. Umbilical duct. f,g. Amnion. h. Point of union of cephalic and caudal involucra. i. Cavity filled with liquor amnii. l. Urachus. m. Allantois. o, p. Chorion.

To return to the ovum, *Bischoff* found that of the dog about 3 lines long, and half as wide between the 12th and 16th days. The area germinativa becomes surrounded by a less clear space, termed the area vasculosa, and in it appears the first trace of the embryo as the "primitive streak." The edges of this groove are termed the "dorsal laminæ," and they rise up and arch together to form the spinal canal. Two "ventral laminæ" also project downwards and enclose the viscera. The anterior or cephalic end of the embryo enlarges, and three vesicles, the rudiments of the brain, become apparent. About 24 hours after the formation of the primitive streak the amnion begins to form, and soon contains liquor amnii which bathes the embryo. The amnion is continued along the cord to the integument of the embryo.

The relations of the embryo and its coverings will be understood from a careful study of the annexed figures.



Human Embryo, after the figure in Müller's Physiology, from a preparation by Prof. Sharpey.

1. *Chorion.* 2. *Amnion.* 3. *Umbilical vesicle.* 4, 5, 6. *Intestine.* 7. *Umbilical vein.* 8. *Vena portæ.* 9. *Liver.* 10. *Filament of umbilical vesicle, probably omphalo-mesenteric artery.* 11. *Filament, probably omphalo-mesenteric vein.* 12. *Umbilical artery.* 13. *Sheath of cord.* 14. *Eyeball.* 15. *External ear.*

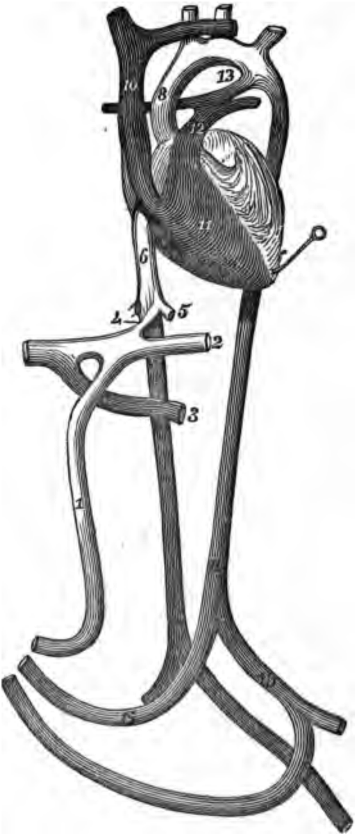
The liquor amnii flows into the œsophagus and trachea of the fœtus. It is a yellowish acid fluid containing chloride of sodium and other salts, a trace of albumen, urea, and casts of the uriniferous tubes, which prove that the fœtal urine is poured into this fluid. The umbilical vesicle is very small in the human embryo, lying between the chorion and amnion, its duct communicating with the intestine, but it disappears early.

The Allantois is a sac formed on the front of the lower end of the embryo. It holds the secretion of the Wolffian bodies and conducts the umbilical vessels to the placenta, and disappears as soon as they unite to it. The allentoic fluid contains chlorides, lactates, and phosphates, and a peculiar substance, analogous to uric acid, termed allantoin.

The development of the most important organs and tissues have been before alluded to, but here the Wolffian body may be noticed. It is an oval body which lies in front of the kidney and supra-renal body, being so large as to conceal them. Several tubes exist in them which secrete a fluid, poured by a duct into the sinus urinogenitalis, or fœtal cloaca. They act as temporary kidneys and disappear, with the exception of the parovarium—a tubular mass in the hilus of the ovary—and the organ of *Giraldés*, above the testis, which *Kobelt* has proved may become the seat of encysted hydrocele.

The Umbilical Cord connects the fœtus and the placenta, and is covered by the amnion. It contains a soft, protective structure, which *Wharton* described, in 1659, as gelatin, but which has a beautiful cellular arrangement like the vitreous body; one umbilical vein carrying blood from the placenta, and two umbilical arteries returning it; the urachus, or remains of the allantois; the omphalo-enteric duct; and the omphalo-mesenteric vessels.

The Fœtal Circulation may be here briefly sketched. The umbilical vein (1) carries pure blood from the placenta and enters the fœtus through the navel, runs to the liver, and divides into branches to left side (2), and one to the right, which joins the porta (3), as has been



1. *Umbilical vein.*
2. *Its left division.*
3. *Vena portæ.*
4. *Ductus venosus.*
5. *Hepatic veins.*
6. *Vena cava.*
8. *Arch of aorta.*
9. *Descending aorta.*
10. *Superior vena cava.*
11. *Right ventricle.*
12. *Pulmonary artery.*
13. *Ductus arteriosus.*
14. *Bifurcation of aorta.*
15. *Iliacs ending in umbilical arteries.*

The Fœtal Circulation.

explained at page 183. The blood is then carried by the ductus venosus (4), to the left vena cava hepatica (5), and henceforward it is mixed. The cava (6) brings it to the right auricle, but directed by the Eustachian valve and tubercle of *Lower*, it passes through the foramen ovale to the left auricle. From this cavity it enters the left ventricle, and is thence propelled, through the aorta (8) to the head, neck, and upper extremities, and returning by the superior cava (10) to the right auricle, it decussates the current from the inferior, according to *Sebatier;* but *Winslow* believed that the two kinds of blood were here intimately mingled. Leaving the right auricle a second time, it passes to the right ventricle (11), which forces it through the pulmonary artery (12), a little being distributed for nutrition to the lungs, but the main bulk, entering the ductus arteriosus (13), passes into the aorta below the branches which are sent to the upper part of the body. As the two ventricles contract synchronously, the purer blood in the aortic arch is prevented from passing to the lower part by the current entering through the ductus arteriosus. The blood is returned to the placenta by the two umbilical arteries (15) which come off from the iliac. The fœtus is then supplied with but partially ærated blood, and for this reason, as well as the non-development of the cerebro-spinal functions, it has been placed lower in the scale of animals than the mature creature; *Bichat* oddly considered it to rank with the invertebrates.

The human fœtus is carried about 280 days, when the womb becomes excited to expel its contents by the accession of the tenth menstrual period, the ovarian nerves being excito-motor, and the uterine reflecto-motor. By successive pains, or uterine contractions, aided by the abdominal muscles, the membranes are forced through the vagina, and, bursting, discharge the liquor amnii. The head is usually the first part born, the body soon following. Shortly after, the placenta, decidua, chorion, and amnion are thrown off, constituting the "after-birth." The muscular contraction of the uterus prevents any considerable hæmorrhage, and that organ, by the fatty degeneration of its tissue, slowly returns to its former size, after the wonderful process in which it has taken so important a part.

CYCLICAL CHANGES—INFANCY, MATURITY, OLD AGE, DEATH.

With birth the developmental changes are by no means over, for man is slowest of all animals in attaining maturity. The average weight of the infant body is 6 pounds, the upper part of the body much exceeding the lower in proportional size. The relative weight of organs of the fœtus to the adult are given as follows by *Dalton*, on the standard of 1,000 :

	Fœtus.	Adult.
Weight of entire body	1000·00	1000·00
Encephalon	148·00	23·00
Liver	37·00	29·00
Heart	7·77	4·17
Kidneys	6·00	4·00
Supra-renals	1·63	0·13
Thyroid	0·60	0·51
Thymus	3·00	0·00

The lungs gradually dilate, while the ductus arteriosus shrivels, closing first at its aortic end. So soft and vascular is the skin, that it is believed to aid the lungs as a respiratory surface shortly after birth. The unctuous matter, or vernix caseosa, which prevented the liquor amnii from soaking the fœtus, and the soft down or lanugo which covered it are removed. We have elsewhere noticed that independent calorific power is not so active in early as in adult life. The infant sleeps the greater part of its time, the function of innervation and the special sense endowments slowly developing. The nervous acts are mainly of the reflex kind—a remark which applies still more forcibly to convulsions and some frequently fatal infantile diseases.

The important epochs of dentition and puberty have been before alluded to.

The hereditary transmissiom of peculiar characters was believed on all sides, until *Buckle* lately threw much doubt on the subject; but the transmission of disease, diathesis, or deformity in this way, of which every practitioner must have evidence, supports the opinion. The influence of the male has been said to bear more upon the apparatus of animal life, as the spermatozoa do not probably reach deeper in the ovum than the serous layer of the germinal membrane; while the mother is more apt to share peculiarities in the organs of vegetative life. The phenomena of atavism, in which peculiarities will appear in a third generation, are still more strange; but it may be supposed some more powerful tendency quelled the peculiarity in the intermediate generation.

Old Age might be characterised as a gradual process of dessication, for the proportion of water diminishes in all the tissues, and rigidity of the muscles and joints ensues. To the same cause may be also assigned the obtuseness of the organs of innervation and special sense.

Death has been divided into somatic, or that of the body at large, and molecular—the occurrence of rigor mortis marking the distinction between them. Life has been confessedly hard to define, and a corresponding difficulty occurs with regard to death. The definition of life proposed by *Beclard*, viz., " organization in action," is at least short and intelligible, and death may be similarly defined to be its arrest for ever.

As *Bichat* first demonstrated, the heart, lungs, and brain are so essential, that they may be designated "the tripod of life," and death may begin by failure in function of any one of these.

The Heart may fail suddenly—syncope; or gradually, asthenia. The former is usually the result of some sudden lesion of the nervous centres, or the rapid removal of a large quantity of blood. Violent mental emotions and certain poisons, such as digitalis and tobacco, are supposed to act similarly. The heart is found usually firmly contracted after death. Exhausting diseases, as fevers, peritonitis, dysentery, produce death by asthenia, and the heart is, in this case, found flabby and soft.

The Lungs may fail in their office, and hence arises the condition known as asphyxia or apnœa (see p. 165).

The Brain may fail, and, as a consequence, death by coma is said to take place; but in many instances where the medulla oblongata is the part affected, the result assumes the form of asphyxia. In many cases death is not due to a single one of these causes, but to the concurrence or rapid sequence of them all.

The preceding remarks have important practical applications, for in diseases of uncertain site—for instance, fever—it is the duty of the physician first to determine, and then to strive against the tendency towards each mode of death.

Many of what are called the signs of death are equivocal; they are usually enumerated as cadaveric aspect of the face, stoppage of the circulatory and respiratory movements, as ascertained by the stethoscope; coldness, and lividity of surface, rigidity of muscles, and lastly, which is quite infallible, putrefactive change.

The death which we have been discussing is but the death of the Body; for to the Soul, as the Christian delights to feel, it is a new birth to a glorious, interminable Future.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Can any organic form be generated spontaneously?
2. Describe the structural anatomy of the testis, and compare it with that of the kidney.
3. Say what you know of spermatozoa.
4. Contrast generative capacities in the sexes, and say what changes take place at the menstrual period in woman.
5. What evidence of impregnation does the ovary exhibit, and contrast it with the appearance dependent on menstruation?
6. What are the decidua?
7. Trace the fœtal circulation.
8. What covers the skin of the new-born child?

SENIOR.

1. Sketch out the sub-divisions of reproduction.
2. Explain and exemplify alternation of generations, parthenogenesis, and the origin of species by means of natural selection.
3. Describe the muscular and erectile structures which surround the urethra.
4. Describe the unimpregnated ovum, and state the changes which occur after impregnation up to its reaching the uterus.
5. What immediately surrounds the body of the fœtus? Detail its composition and uses.
6. Describe the development of the temporary kidneys. Does any remains of them ever come under the notice of the surgeon?
7. Give examples of hereditary transmission, and explain what is meant by atavism.
8. Sketch the more positive signs of death, and how has it been divided according to the organs primarily engaged?

THE PRINCIPLES OF DISEASE.

Pathology, the science of disease, is either General, including such important morbid conditions as those that affect the circulating fluid or the great textures of the body; or Special, of which the former alone concerns us here. In sketching these abnormal physiological changes, we shall, firstly, discuss those of nutrition; secondly, those of innervation; and, lastly, those which depend on the invasion of some foreign being, vegetal or animal.

So important are the pathological conditions of the blood, that after *Galen's* time it was supposed that in this fluid lay the essence of all disease, till *Baglivi*, *Cullen*, and others asserted that the solids were the exclusive seats of morbid change. Hence arose the great doctrines of humoral and solidistic pathology, between which, we shall find, the truth lies.

Blood diseases consist in either an increase or decrease of the amount of the circulating fluid, or of some of its constituents, or in their degeneration.

Hyperemia, or plethora, equally signify that condition in which the whole mass of blood is excessive. It occurs in persons of the sanguine temperament, and is due to increased ingestion of nutriment without corresponding expenditure. Amputations were formerly said to be often followed by plethora; but the loss of blood during the operation, and the constitutional condition of the patient when it is now performed, render such an event very rare. The red-cells are especially increased, even to the amount of 185 per 1,000, giving the fluid a most florid hue. The pulse is quick and strong, the vessels of the neck are full and throbbing, and there is great liability to hemorrhages and inflammatory diseases.— Low regimen (which has been found to decrease the proportion of red-cells from 132 to 85 in 15 days) and evacuants are plain curative indications; moreover, the production of any suppuration—as by a seton, or mercurial purges, which stimulate the liver—are most efficacious in diminishing the red-cells.

Anemia, or bloodlessness, properly means decrease of blood, but is often applied to the condition to be next described—in which the red-cells are proportionally scanty, though other constituents are in normal amount. It is usually the result of hemorrhage, and its signs and curative indications are precisely the reverse of hyperemia. I have lately had a patient who, by bleeding piles, was so blanched, that there was no difference in colour between the mucous and cutaneous surfaces of his lips, and the blood which flowed from a small accidental wound was of a perceptibly pale hue. When loss of blood is sudden, the operation of transfusion is advisable, and any sudden alteration in the position of the body should be avoided. Free open air exercise, abundant nutriment, tonics, and chalybeates are clear indications.

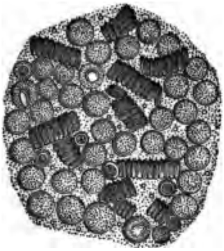
Spanemia, or poor blood, a term applied by *Simon*, expresses that condition in which the red-cells are less numerous than they are normally. It is best seen in chlorosis (in which the proportion has fallen as low as 27), and also is produced among our more wretched town population by want of proper food, light, or ventilation, and by the action of mercury, lead, and other poisons. Mercury especially destroys red-cells by stimulating the liver to increased action, and their colouring matter is thrown off as that of bile. The green stools of children, while taking the drug, are altered hæmatin. Morbid states of the menstrual function are generally connected with chlorosis. Woman forms, while the procreative capability lasts, blood both for her own body and that of an infant; so that, if the latter be not consumed by the demands of pregnancy or lactation, it is got rid of by the uterine surface every month. If the menses are retained by some cause which is very often mechanical, plethora results, and is relieved by the establishment of some vicarious hemorrhage, as from nose or stomach. Thus, amenorrhœa may be accompanied by plethora, but is much oftener attended by chlorosis, the condition of blood being the primary one, and the menstrual flow stopping because there is no blood to spare. Menorrhagia, like other hemorrhages, will produce anemia. The pale, greenish hue, with lips and gums almost as bloodless as the skin; the small clot, often buffy, owing to the disproportion between the fibrin and red-cells; and the abundant serum, are characteristic of chlorosis. Either from the collapsed state of the vessels, the thin state of the blood, or the friction of its shrivelled cells; a bruit or murmur can be heard as it passes through the superficial veins. Iron is almost a specific in treating spanemia, raising in a few weeks the proportion of red-cells from 82 to 95 per 1,000.

Hydremia, or watery blood, often precedes dropsy, being accompanied by a deficiency of albumen, which, if decreased as low as 60, will allow the blood to ooze through the vessels. Increased ingestion of water will not produce hydremia, if the organs of secretion are active. In Bright's disease the loss of albumen by the kidneys lowers its proportion in the blood and leads to dropsy. In one case *Dr. Bright* found the specific gravity of the serum but 1·013. From the diminished specific gravity the red-cells distend, and may rupture, producing patches of ecchymosis; and to some such change has been attributed death after copious draughts of water. The clot is loose and jelly-like.

Anhydremia, or deficiency of water, is a term which might be applied properly to the state of blood in cholera. Its specific gravity has been found 1·070, and that of its serum 1·045. The blood is viscid and pitchy black, all the solids except salts being in excess, sometimes doubled—having in one case reached the proportion of ·520. Urea abounds in the blood, as it cannot move through the Malpighian capillaries; and there is said to be a peculiar ferment which converts it into carbonate of ammonia. The transfusion of solutions of salts, as proposed by *Stevens*, renders the blood more scarlet, and decreases its spissitude for a time. Dysentery is also said to diminish the water considerably.

Leucocythemia is the name applied by *Prof. Bennett* to a condition of blood in which the white-cells exceed their normal amount, and which he was the first to recognize, in March, 1845. Six weeks afterwards, *Virchow* described the disease under the less accurate term of leucemia. In 1850, *Bennett* first diagnosed the disease during the life of the patient, and obtained blood for microscopical examination by pricking the finger, and its appearances are here depicted. In extreme cases the white have been found to exceed the red-cells in number. Analysts allow that there is no way of separating the white-cells from the fibrin, and we have before alluded to their probable identity. In this case the blood consisted of

Water	854·5
Fibrin	6
Red-cells . . .	67·5
Serum solids . .	72
	1000·0



White-cells, and red-cells adherent, in the case here mentioned.

The most remarkable feature of the disease is the great enlargement of the ductless glands—a fact which points plainly to their action in sanguification. The spleen has been found to weigh over 9 tbs., and the thyroid, suprarenals, intestinal gland-cells, and lymph glands, have been found enlarged, soft, and filled with abundant juice. *Prof. Ben-*

nett remarks—"In certain hypertrophies of the lymphatic glands in man, their cell elements are multiplied to an unusual extent, and under such circumstances find their way into the blood, and constitute an increase in the number of its colourless cells. A corresponding diminution in the formation of free nuclei, and consequently of coloured corpuscles, must also occur. This is leucocythemia. As regards treatment, nothing that I have yet tried has appeared to be of the slightest service in well-marked cases of leucocythemia, associated with distinct glandular enlargements." In the best marked case of leucocythemia I have ever met—the patient being a farmer, whom I saw in consultation with *Dr. Davys*—the peculiar state of the blood and the glandular increase followed upon pleural effusion, which completely collapsed one lung. Death is usually preceded by great passive hemorrhages.

Hyperfibrinosis seems preferable of the many terms which have been applied to an increase of fibrin in the blood. The term hyperinosis is synonymous, and the condition has been named by some pathologists "hematitis," or inflammation of the blood. The specific gravity is lowered, owing to the relative diminution of red-cells, which are the heaviest element of the blood. They often form into piles or rouleaux, as represented at page 107, and so produce a mottled appearance in a thin film, as *Hunter* noticed. It is more highly oxygenated, and to this may be due the high temperature of it, which has attained 112°. However, the characteristic feature is increase of fibrin, or white corpuscles—which I am confident further pathological investigations will prove to be identical. This increase is shown by greater viscidity of the serum and the slowness of coagulation, producing a clot which forms the buffy coat on its surface; and under this nearly always lies a layer of white-cells, which, owing to the exclusion of oxygen, have not undergone conversion into fibrin. The causes of hyperfibrinosis are most various—thus inflammations, especially of such organs as are freely supplied with lymphatics—lung, liver, &c.—*Virchow* has shown, vastly augment the amount of fibrin, even to the proportion of 13·3, while phrenitis scarcely produces any such effect. Rheumatic fever is well known to produce similar increase, because it is an inflammation of parts freely supplied with lymphatics—or, as it occurs to me, the fibrin is not removed from the blood to repair muscular waste, almost complete immobility existing. Disease produced by animal poisons, as the eruptive fevers, are often attended by this increase of fibrin in their accession.

Hyperfibrinosis may be produced artificially by making animals breathe more oxygen while at rest; but if active exercise be taken, the excess is got rid of. This and other facts have led *Dr. Gairdner*, Professor of Medicine in Glasgow University, to believe that, as regards the blood, "oxygenation and fibrillation are identical." Its more frequent deposition, as valvular clots on the left side of the heart, is explained by these facts. The occurrence of rigors in the beginning of inflammations has been explained by the abstraction of oxygen to convert albumen into fibrin producing a loss of heat; and their recurrence, if suppuration follows, to still more of that element being required to form the more highly oxidised compound which pus contains. Fibrin, but of an inferior character, is abundantly produced in the blood in tuberculosis and cancer, as will be hereafter mentioned. Neutral salts, which preserve the fluidity of the fibrin, and such oxidising agents as chlorate of potash, or permanganate of potash, which is well worthy of trial, are indicated in cases of hyperfibrinosis.

To the condition in which the proportion of fibrin is decreased, or in which it is even absent, the term hypinosis or afibrinosis is applied; but as such is seldom the only pathological change, its separate consideration may be scarcely necessary. *Wedl* regards it as identical with the state he describes as "albuminosis." The blood scarcely clots owing to the superabundance of ammonia, for *Simon* always found the blood alkaline, and there could be found no fibrin but carbonate of ammonia in one case of putrid fever. It is frequently a result of the introduction of the paludal or malarious fever poison, having been lowered to the proportion of 0·9 in cases where recovery afterwards took place. Deficiency of fibrin has been also discovered in cases of hemorrhagic diathesis—a peculiarity which is often hereditarily transmitted—typhus, mania, and some other diseases, especially those which impede respiratory action; and likewise in that morbid state, cyanosis, which is usually congenital, the blood is almost entirely venous and contains fibrin very scantily.

As to the morbid variations which the proportion of salts undergoes, we know but little. Their proportion has been found very low in inflammations, thereby tending to produce the coagulation of the blood within the vessels which is characteristic of that process, and greatly increased in typhus—producing the opposite effect. Scurvy, and perhaps purpura, are due, according to *Dr. Aldridge*—and the remark was confirmed by *Garrod*—to a deficiency of potash salts; hence the efficacy of uncooked vegetables, lime juice, fresh meat, &c., in preventing or relieving those diseases. My former pupil, *Dr. D. Walker*, of the late Arctic expedition, informs me that the juice or blood of meat seemed to possess, mainly, the prophylactic properties. It was, therefore, always given underdone. [See page 55, and also my "Lectures on Public Health," where I have also discussed the connexion of a want of phosphorus and scurvy.] This theory of deficiency of potash salts has been much opposed, and is at variance with the valuable analyses of *Mr. Busk*, who found the salts increased from 6·8 (the normal proportion) to 9·5, 10·9, and 11·5, in 8 cases of scurvy. The extravasation of blood which occurs is generally attributed to a thin state of the blood (the hematin of which, according to some, is alone effused), but may be due to some weakened or ill-nourished state of the capillary vessels. The earthy salts have been found diminished in proportion in cases of rachitis; and in old age they have been supposed to be removed from the bones and carried to the vascular and fibrous tissues, producing calcareous degeneration and chronic rheumatism, the pain of which is thus accounted for.

The effects resulting from increasing the specific gravity of blood by adding to it crystalloids—such as saline substances and sugars, or bodies that act like crystalloids, specially alcohol—have been demonstrated by *Dr. Richardson*, of London, who maintains that cataract arises from increased specific gravity of blood, and that cirrhosis of the liver is purely a physical change produced from a similar modification of blood.

Fatty matter may be excess in the blood, and is denoted by the opalescence of the serum, and has been said to attain the proportion of 117. This condition has been found to precede the pathological state termed fatty degeneration, which will be presently noticed. The normal amount of fat in the blood is said to be decreased in phthisis.

Cholemia, or the condition of the blood in jaundice, may result from—1. A superabundant formation of the materials of bile, or their being received into the blood in excess. 2. A failure in the action of the bile-secreting cells of the liver. 3. An obstruction to the discharge of the bile through its ducts, followed by the re-absorption of some of its constituents into the circulating fluid. The serum, buffy coat if formed, all the secretions, and many of the tissues become stained by the biliphœin. Cholesterin, cholic acid, leucin, and tyrosin have been detected in the blood. The kidney, for a long time, staves off injurious effect, for by excreting urophœin, purpurin, and other highly carbonaceous materials, its office is somewhat vicarious to the liver. Much more formidable symptoms follow the non-secretion than the reabsorption of bile. The remarks on the functions of the liver we have previously made, may be now advantageously referred to.

Another retained matter, urea, gives rise to that very frequent state of blood, uremia—which has been before briefly discussed when treating of the physiology and pathology of the kidney—the organ by defect of which its retention ensues. Glycemia, or the increase of sugar in blood, has been also described in the same section. Again, evidence is every day accumulating that gout, rheumatism, cutaneous eruptions, and many other diseases are due to failure of some excretion from the blood.

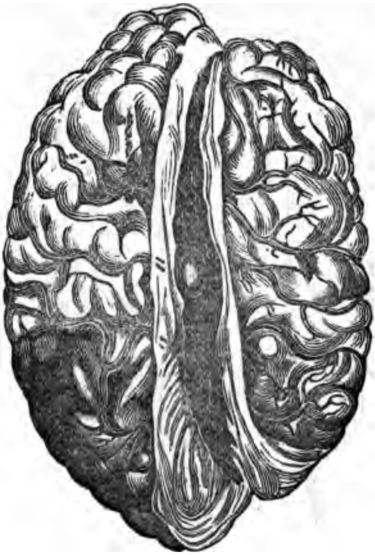
Pyemia was the name applied to the entrance and diffusion of pus through the blood; but as white blood-cells and pus-cells are indistinguishable, it is now very generally believed they have been mistaken for each other. In this way were accounted for the disappearance of abscesses, their metastatic discharge by the kidney or bowels, or the sudden deposit of pus in the lungs, liver, joints, and other places. However, from the size of the cells, pus, as such, can never be absorbed, but it may disappear by either of the following methods—the liquor puris may be absorbed and the cells may concrete into an almost solid mass of cheesy matter, found in dried up abscesses, strumous glands, and tubercle, which, according to *Reinhardt*, is in this way formed, and is always the result of inflammatory action. The second method in which that fluid may be removed is by fatty degeneration, in which the pus cells break up, and a fatty, saccharine, and albuminous fluid, aptly compared to milk, results, and which may be afterwards completely absorbed. The veins have been thought to be so ready a channel for the transmission of pus, that phlebitis and pyemia have been considered almost synonymous terms, and the lymphatics were also supposed to carry that fluid ; but the fact of mineral substances used in tattooing the arm, and the matters of cancer and syphilis being arrested in their glands, renders this latter hypothesis improbable. When the so-called pus is found in veins, it always lies in the centre of blood-clots.

I shall quote the opinions of *Morgagni*—an ancient but surprisingly accurate pathologist. In his book, "De Sedibus et Causis Morborum," he says wounds and blows upon the head "give origin to the generation of a much more copious pus than what is carried thither; which generation is shown by those rigors and horrors. And by this means we may also conceive how it is that much more pus is frequently found in the viscera and cavities of the bodies than a small wound could have produced."

The lymphatic glands, or the organs which make the white-cells, are known to increase much during pregnancy, and they fill the blood with numerous white-cells or much fibrin, a fact which may account for the readiness with which the then so-called pyemia is excited, and for the fatality of scarlatina and other zymotic poisons if they attack women in this condition. Suppuration in joints, serous cavities, and other distant places in cases of phlebitis, seems to be the combined result of local inflammation and abundance of corpuscular fibrin in the blood.

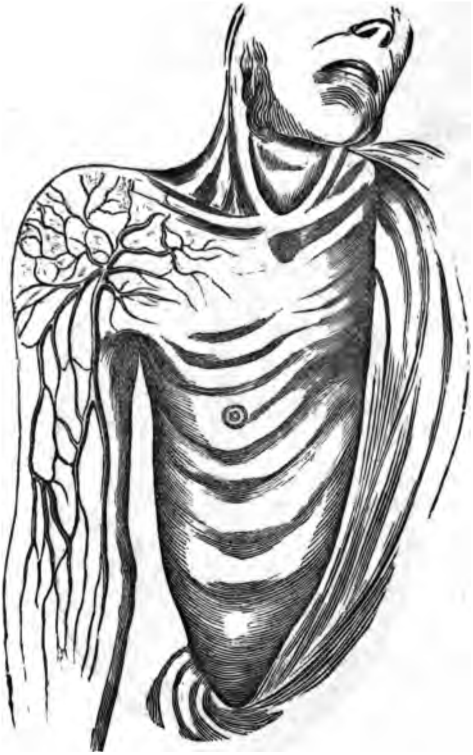
Thrombosis is the name applied by *Virchow* to that condition in which clots, often with a puriform interior, form in the heart or blood-vessels; and the portions of these which may become detached, and block up other vessels, are named emboli. These emboli may entirely occlude the vessel; or if they have entered the pulmonary artery, as they most frequently do, they may cause asphyxia, or may be impelled onwards into the capillaries of the lungs, and there excite limited spots of inflammation. The blood has been found to have an acid reaction in some of these cases. The whole subject of embolism, and its connexion with cerebral softening, apoplexy, pneumonia, gangrene, and some forms of sudden death, is full of interest; but to treat of it here at greater length would be to trespass on the domain of special pathology.

One of the best accounts of the subject in our language may be found in a lecture of *Mr. Richardson's*, "Medical Press," March, 1863, from which the following illustrations are borrowed. The first represents the superior longitudinal sinus, the seat of thrombosis—a clot, and apparently purulent fluid occupying the cavity, as re-



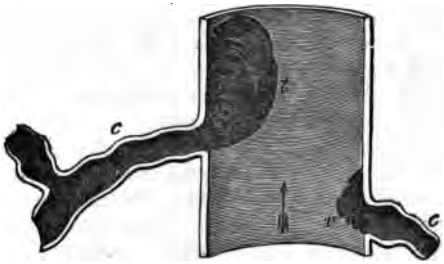
Thrombosis of the Superior Longitudinal Sinus—the right cerebral hemisphere atrophied (Mayne).

corded by the great physician *Dr. Mayne*, before the Pathological Society of Dublin. The next shows the dilated state of the superficial veins which ensued from phlebitic obstruction of the innominate vein; and the two succeeding, after *Virchow*, the mechanism of the process of

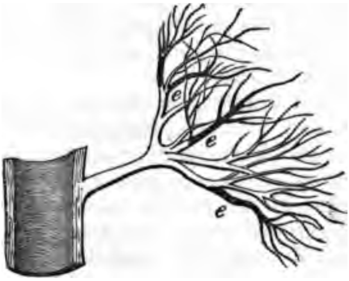


Dilated state of Superficial Veins from thrombus in right innominate vein.

thrombosis. The spanemic effects of mercury seem to contra-indicate its employment in these affections.



A Venous Trunk and two of its branches, the seat of thrombosis.
c, c. Thrombi. t. Venous trunk. v. Thrombus becoming detached by the current, to become wedged in small vessels, and produce obstruction or metastatic deposits.



Splenic Vessels with Thrombi (e, e, e) impacted in the capilliaries.

Toxemia implies that condition of blood which results from the introduction of a morbid poison—especially those of animal origin, as scarlatina, syphilis, glanders, hydrophobia; and the consequent diseases are among those grouped together by the Registrar-General as zymotic. They differ widely from ordinary mineral or vegetal poisons, in acting in extremely minute quantity and scarcely in proportion to the dose, and in multiplying themselves enormously by zymosis or fermentation in the blood, so that they seem to exhaust all fermentable material, and never again can be developed in the same individual. To this statement, according to recent pathologists, syphilis seems not to be an exception. They are communicable in the solid, liquid, or gaseous form, and they all seem to have, like most of the mineral and vegetal poisons, some special seat whereupon they fix when inoculation has taken place.

The following facts may be regarded as proof that fermentation, or putrefaction, and the zymotic process in many diseases are analogous. Decomposing human tissue gives rise to most serious blood poisoning, which may be also excited by putrescent sausages and other animal foods. Many anti-septics, such as the sulphites and pyroligneous acid, check the progress of blood-poisoning; and lastly, ammonia—that constant product of animal decomposition—is always found in the effluvia, and combined as the ammonio-phosphate of magnesia occurs in the stools of typhus, one of the most decided of these zymotic diseases.

So rapid and immense is the generation of these poisons, that they have been supposed to be due to infinitely minute parasitic animals or plants introduced into the blood, in which they re-produce their kind. That beings can exist in this fluid is proved by the presence of the animalcule distoma hœmatobium; and *Dr. Goodfellow* discovered thread-like animalcules from $\frac{1}{3000}$ to $\frac{1}{5000}$ in length in the blood of a fever patient. Although the chemical or fermentation theory of morbid poisons propounded by *Liebig* is as yet crude and unsupported, there is little doubt but that that most useful of the sciences auxiliary to medicine, organic chemistry, will yet discover their nature and properties. That it is upon what are called "extractives" they mainly act, is argued as follows by *Mr. Simon*, the Medical Officer of the Privy Council, in his admirable "Lectures on Pathology:"

"For, in the first place, they are matters already in progress of decay, and therefore eminently susceptible of new modification; in the second place, they are inessential to the nutritive processes, and that removal of them from the system which would give immunity from reinfection might be accomplished without withdrawing a vital ingredient from the blood; in the third place, only of such matters as these can it be said that some of them occur but once in life. In infancy, in early age, and till puberty, there are certain waste materials which never afterwards occur; the temporary cartilages have to waste away, the thymus gland has to decay, peculiar changes referable to the sexual system have to be accomplished, and the effete products of these changes have to be eliminated from the system. And, fourthly, notice that the surfaces and organs most prone to affection in the diseases under consideration are those which are eliminative and defecating; those whose normal products can hardly be retained for any time within the body, much less out of it, without undergoing a fœtid decomposition, which sufficiently stamps them with an excrementitious character. Bowels, skin, kidney, tonsils, are the favourite resorts of the several fever-poisons, just as they are the surfaces by which naturally the organic waste of the several tissues is eliminated. And it may not be amiss to notice that, whereas the normal and healthy discharge of these substances commonly tends to occur in the highest attainable form of oxidation; and whereas, under a variety of atmospheric circumstances interfering with their efficient oxidation, they must tend to accumulate in forms more susceptible of fetid decomposition; so it is peculiarly under such circumstances—where ventilation is defective—where human beings are unduly crowded—where the air is loaded with deoxidizing influences—that zymotic diseases tend to affect the system, either through a new generation of their poison, or through some vast increase of susceptibility thus engendered."

While preventive measures are undoubtedly efficacious, in no class of diseases must the physician depend more entirely on the "vis physiologica vel medicatrix naturæ;" that is, he should rely on a free supply of air, and other attentions to the normal functions such as are generally termed hygienic treatment, endeavouring, meanwhile, by nutriment to sustain life till the poison has been eliminated. *Dr. Richardson* of London has shown that in some of these diseased conditions, the breathing being normal, the patient sinks for the sole and simple reason that the blood will not take in the oxygen that is brought to it. In such cases the blood is charged with compounds which by their presence prevent oxygenation—precisely as antiseptics prevent that process out of the body. In typhus this is the common mode of death, and he terms it asphyxia commencing in the blood.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. What have been the two most remarkable theories as to the seat of diseases?
2. Enumerate a few causes which increase or decrease the red-cells of the blood.
3. What results follow the increase or decrease of water in the blood respectively?
4. Are leucocythemia and hyperfibrinosis allied to each other?
5. What obvious pathological conditions accompany leucocythemia?
6. In what cases has a deficiency of fibrin been found?
7. Is pyemia possible?
8. Enumerate the chief zymotic diseases, and explain their nature. What chemical change of the blood do they interfere with?
9. What are the preventive and curative measures available in zymotic cases?

SENIOR.

1. Explain the action of remedies in cases of hyperemia.
2. Sketch the action of various causes in producing spanemia, and its symptoms.
3. By whom, and how, was leucocythemia discovered?

4. Mention some inflammations which do, and which do not, increase the fibrin in the blood.
5. State two theories of the cause of scurvy, and the facts and arguments which support them.
6. What are the proximate causes of cholemia ?
7. Describe the condition of veins when blocked by thrombi.
8. Explain the diffusion of thrombi, and enumerate some consequent diseases
9. Sketch the analogies between zymosis and fermentation.

ABNORMAL NUTRITION.

UPON a careful review of all pathological processes, it will be found that there are very few of them which cannot be referred to a decrease, increase, or perversion of the function of nutrition. This will be evident from an examination of the following table, adapted from the great work of *Dr. Williams* with some slight modifications:

NUTRITION.
- Decreased .. Atrophy.
- Increased .. Hypertrophy, Repair, Inflammation.
- Perverted
  - Effusions.
    - Plastic.
    - Cacoplastic.
    - Aplastic.
  - Degeneration.
  - Growths ...... Tumours, Cancer.
  - Physical alterations.
    - Hardening.
    - Softening.
    - Contraction.
    - Dilatation.
    - Obstruction.
    - Compression.
    - Displacement.
    - Rupture.

These conditions we proceed to sketch, referring for the many details of special diseases to treatises on medicine and surgery.

Atrophy implies a wasting of any part, the result of decreased nutrition, or of interstitial absorption when it occurs faster than new material is laid down. It is not always abnormal, as such parts as the gubernaculum testis and thymus are removed in early life, and the mammary gland, spongy structure of the penis, and the testis are reduced when they have fulfilled their office. Its most frequent cause is disuse, thus the muscles and bones of paralysed limbs rapidly waste unless the artificial stimulus of electricity be substituted for the natural one of nervous force, which has been impaired or lost. A diminished quantity or inferior quality of blood will surely lead to atrophy of any part, as also will interference with the influence which we have seen the nervous system possesses over nutrition. The contraction of the calibre of arteries by increased action of their muscular coat is a frequent cause of atrophy, and the chronic gangrene which spurred rye produces may be explained in a similar way. Pressure, if constant, leads to atrophy; if occasional, to hypertrophy—which explains *Hunter's* remark, that pressure from within causes thinning; from without, thickening of parts. Atrophy may be general, marasmus; or partial, a condition from which no organ is intact. Atrophy is often combined with, or preceded by alteration in quality as well as quantity, as will be stated when discussing fatty degeneration. The curative indications clearly consist in securing a due supply of the nutriment of the wasted organ, and in promoting its activity by exercise.

Hypertrophy is the converse of the state we have just examined, and consists either in an increase in size of the materials which constitute a part, or an increase in their number. These two varieties *Virchow* distinguishes as simple and numerical. For the production of hypertrophy the following conditions are necessary: 1. Increased exercise of function; 2. Increased amount in the blood of the special materials of the part; and 3. Increased afflux of blood. Hypertrophy, unlike atrophy, is never general; but, like it, it may be normal, as when an ordinary muscle augments in bulk; but if the muscle be the heart the alteration is fraught with danger, as we know it is usually the result of valvular disease, and the cause very frequently of sudden death by rupture of the cerebral vessels. Both these occurrences, as well as the hypertrophied or columnar bladder in urethral stricture, are the result of the first condition we have enumerated, Increase of adipose tissue, or obesity, is an example of the second circumstance, and the reader will find this subject discussed in my "Lectures on Public Health." No more forcible example of the action of the third condition could be adduced than the vast increase of the cock's spur when transplanted to the more vascular comb. In hypertrophy all the excess of blood is utilised or converted into tissue similar to that of the organ, but in inflammation it is wasted in the formation of new products. In double glands, or glands of similar office, the impairment of one leads to vicarious hypertrophy of the other. *Virchow* believes that nervous influence is not necessary in order that parts should take up an increased quantity of materials, for in parts "entirely destitute of nerves, as, for example, the surface of an articular cartilage, we can, as was shown many years ago by beautiful experiments of *Redfern*, produce altogether similar effects by means of direct stimuli."

REPAIR.

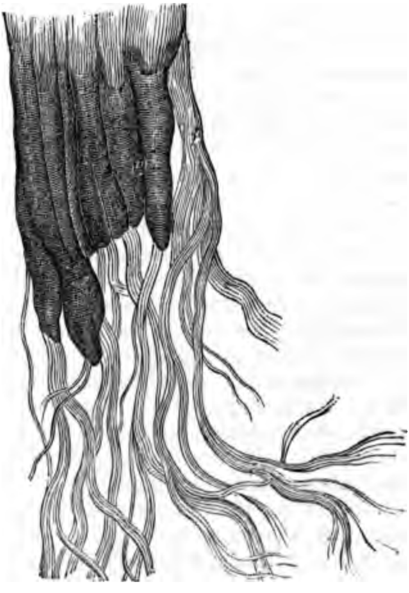
Although the reparative process cannot be regarded as in itself abnormal, it may be conveniently considered here, as it is an increased condition of nutrition, and it follows injury or disease. *Mr. Paget* explains that something similar occurs in inorganic matter; if, for example, a crystal of alum be broken, it will repair itself if placed in a solution of that salt. The process is more powerful in the humbler animals, as shown by experiments on the hydra, which can be divided into many pieces, all of which repair the loss sustained, and become complete animals. Crustaceans also will even perform a voluntary amputation of one of their claws, when disturbed, and it is rapidly reproduced. In the human fœtus, spontaneously amputated limbs attempt reproduction; and *White*, in 1785, related that a supernumerary thumb was formed twice after removal.

We will consider cicatrization before treating of the inflammatory process, which, so far from being essential, was shown by *Prof. Macartney* of Trinity College, in his great work, to be always obstructive of the event. *Paget* enumerates five methods by which soft parts may unite: 1. Immediate union; 2. Primary adhesion; 3. Granulation; 4. Secondary adhesion, or the union of granulations; 5. Scabbing. *Hunter* believed that blood might form the bond of union, and in internal parts clots do occasionally become organized. 1. Immediate union was first shown by *Macartney*, and may follow if the wound be cleanly incised, be closed at once, and all blood pressed out. 2. The second method is more usual. The sides of the wound do not touch, but are united by lymph poured out, as some believe, by adhesive inflammation; this constitutes the cicatrix when organized, but it always remains different from the neighbouring cutis, not containing pigment, hair, or sebaceous glands, if the whole thickness was destroyed. The process may be completed in 48 hours, as we have seen in hare-lip, which is a good example of this method. *Liston*, it is well known, advised that the wound should be exposed till it "glazed;" but then it is very apt to unite in the next way. This is always a very desirable mode of union, save in a few cases—wounds of throat, those in lithotomy, and some other operations; or those made to evacuate a deep abscess, for examples, in which special circumstances compel us rather to keep open. 3. The formation of granulations is usually determined by the access of the oxygen of the air which excites suppuration.

Compound fractures unite in a way quite analogous, but more slowly. *Paget* describes a calm, or inactive period, which lasts for a day or two in vascular parts, or for many days in bone, the blood slowly circulating or even stagnating. The circulation is then aroused, and increased afflux of blood occurs, the granulation matter which had been effused becoming vascularized. Granulations are composed of cells which condense into areolar tissue, the elastic element not forming for many months, so that they are apt to tear open, and do not glide on the subjacent parts. This change of cells into fibres is the cause of those contractions of scars which produce often such terrible deformity. On the surface of the cicatrix cuticle develops, its thickness being in accordance with the surrounding parts. Inasmuch as horny and gelatinous tissues are thus formed out of albuminoids, the process is regarded as one of chemical degeneration. *Hunter* believed that blood-cells and vessels originated in the new material, just as they do in the germinal area; but it may be demonstrated that they merely bud from those of the tissues below the granulations. The vessels so derived loop, elongate, and anastomose; and sometimes, by rupture, a few cells are cast into the tissues, as the blood normally is in insects, and then, by process of "channelling," makes new vessels. Pus covers granulations and protects them; this fluid will be described when discussing the results of inflammation. Though granulations are sensitive and absorb greedily, nerves and lymphatics have as yet eluded microscopists. 4. When two surfaces covered by granulations are placed close together, the cells and vessels coalesce; union being often complete in 24 hours. In deep wounds, sacs of abscesses, &c., the surgeon prefers this mode to the last for its rapidity. 5. In healing by scabbing an air-tight crust is formed of blood, serum, pus, dust, hair, &c., and the scar is more like the original tissue than in any other form of cicatrization, as to its arrangement of cells and elasticity—not contracting and deforming surrounding parts. It is the almost invariable mode in the lower animals. It has been imitated in many plans of healing wounds and ulcers—covering them with lint dipped in blood (*Sir A. Cooper*), filling them with melted wax (*Stafford*), crusting them with nitrate of silver (*Higginbotham*), or with collodion. The process of repair, in a few of the most important tissues, may now be sketched.

1. **Bones when fractured** have the periosteum usually ruptured at the same point, and the soft parts are somewhat torn and infiltrated with blood, which, so far from forming a bond of union, must be removed before that event can occur. Some inflammatory exudation next takes place, and a calm for a week or so succeeds in man—but not in the lower animals, in whom union is therefore more rapid. It is supposed that bones may unite by immediate union, but, far more commonly, lymph, similar to that of granulations, intervenes, and undergoes conversion into bone, cartilage being sometimes an intermediate stage; and both fibrous tissue and cartilage may be the temporary bond of union, the latter lying next the bone. The callus either surrounds the fragments for about half an inch upwards and downwards, forming a ring which *Duhamel* described as the "ferula," or lies exactly between the fractured surfaces; the former is temporary, the latter permanent. *Dupuytren* described a double conical peg (cheville) occupying the medullary cavity; but he was led into error by examining only the fractured bones of the lower animals. Temporary callus is in fact only produced, according to *Paget*, in young animals, and for a like reason—namely, that they are much subjected to motion in the ribs in man. It is the usual mode in children. The internal or cancellous matter has been often found condensed into compact osseous tissue. 2. **Cartilage** undergoing repair has been studied by *Redfern*, and he

finds it is accomplished after many months by white fibrous tissue, the cartilage at the edges of the wound having softened and discharged some of its cells. In fibro-cartilage it is more rapid, and very similar to bone, as the perichondrium forms callus. 3. **Tendons**, when divided in subcutaneous surgery, unite by abundant blastema, which becomes fibrous. 4. **Muscle**, being divided, the breach is never made good by muscular tissue, but by oval nucleated cells, which afterwards develop into such a white fibrous matter as is here represented.—



The Fibrous Matter which unites a divided muscle.

5. **Arteries**, when divided, are rendered impervious, and hemorrhage is prevented by nature's expedients of re-

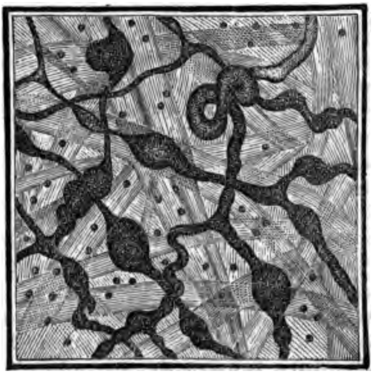
traction within the sheath, contraction of its calibre, and the formation of an external irregular, and internal conical clot, as described in surgical works.

6. The reparation of injured nerves has been alluded to at page 252.

INCREASED VASCULARITY.

Congestion, or the heaping of an undue quantity of blood in a part (local hyperemia), is a precursor of inflammation, but may occur without being followed by that result. Congestion is termed passive when the motion of the blood is retarded; active, when it is augmented. Passive congestion is often produced by venous obstruction, and by atony of vessels—as in fever, when by gravitation the blood accumulates to the back of the trunk, to be often followed by what is termed hypostatic pneumonia. Cold, also, and surgical shock produce intropulsion, and congest internal organs. Active congestion may be normal, as in blushing, or in the determination which often occurs to the reproductive organs, and may occur in diseases not inflammatory—as in epilepsy, in which disease the carotids throb violently, and it is said a fit may be averted by compressing them, and thereby diminishing the flow to the brain. The effect of the sympathetic in regulating the quantity of blood in a part may be advantageously referred to (p. 294). Active or passive hemorrhage (by rupture of vessels—never by exhalation), flux or discharge from a free surface, and dropsy, or effusion of serum into shut sacs or spaces, are usual results of congestion. Passive congestion can never hypertrophy a part, active may.

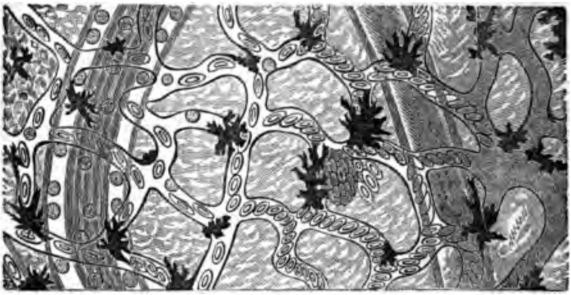
Inflammation, the pathology of which we now proceed to sketch very briefly, has always been regarded as the most important of pathological processes, but the name has been as constantly said to be ill-chosen. So complex are the phenomena, that it is extremely difficult to suggest any appropriate term; and as the word inflammation expresses increased combustion, which certainly does occur, it is perhaps as accurate as any other. It differs from active congestion in there resulting exudation, or the effusion of the solids of the blood. Its principal phenomena are as follows: 1stly. The larger blood vessels are increased in calibre. *Hunter's* famous preparation, still to be seen in his museum, illustrates this. He inflamed one ear of a rabbit by freezing, and when the vessels were injected after death, he found those of the inflamed ear 3 or 4 times as large as those of the sound side. An experiment on a living man proves that more blood flows through them: *Lawrence* bled a patient, who was suffering from a severe whitlow, from both arms, and 3 times as much blood flowed in a given time from the arm on which the local inflammation existed. 2ndly. The microscope reveals the changes in the capillaries; and *Paget*, who selects the wing of a bat, describes the following occurrences: contraction, dilatation, and, finally, stagnation. *Valentin* believes that no increase of the capillaries occurs for their entire



Varicose State of Vessels of an Inflamed Ovary.

extent, but merely in a varicose manner, as here represented; and as red-cells fill the still layer of the capillaries, they seem much larger. The next figure, copied from that in *Prof. Bennet's* admirable Lectures on Medicine, well illustrates the condition of the capillary circulation in the frog's web under health and disease. To the left, the circulation is normal; in the centre, there is congestion and rupture of a capillary, and hemorrhage has occurred; and to the right, inflammation has been excited by the contact of alcohol, and its characteristic results, stagnation and exudation, have resulted. The black stellate marks are pigment granules. New vessels are not formed in inflammation, but those which were only large enough to admit the plasma may then carry the cells of the blood.

Web of Frog's Foot after alcohol has been placed on it.



A Vein — circulation normal – stellate pigmentary cells. | *Deep-seated Artery — very rapid current — capillaries congested, and at one spot burst.* | *Capillaries have become filled with stagnant blood, which has been partially exuded.*

As regards the cause of the appearances we have sketched, or the theory of inflammation, much obscurity prevails. *Williams* believes the stagnation due to the white cells, which are certainly increased, obstructing the vessels, owing to their adhesiveness. The undoubted muscularity of the capillary walls and the influence of the vaso-motor nerves, which has of late years been demonstrated, indicate that the process is vital, not mechanical. *Virchow* states that a muscular contraction of the capillaries first occurs, and is followed by relaxation from exhaustion, as muscular action always is; and, lastly, *Simon*, in his admirable essay on the "System of Surgery," says it is "the result of an increased attraction which the inflaming tissue exerts, as it were, suctionally, on the blood coursing within its capillaries." The inflammatory exudations, which are local results of tissue formation more than products derived from the blood, abound in albuminous matter and in salts, which everywhere seem indispensable where rapid cell-growth is going on. Now, this cell production is most characteristic of inflammation, as plainly illustrated in cartilage, the pathological changes of which, discovered by *Prof. Redfern*, we have before referred to; and in mucous membrane, which when inflamed generates pus cells, instead of the more permanent epithelial cells. Changes in the blood cannot be regarded as the essential feature of inflammation, for it can scarcely be supposed that that fluid is affected before such local inflammations as conjunctivitis can occur. Alterations do, however, result, and have been alluded to a few pages back, and it may be here added, that its temperature is always heightened, as a result of increased oxidation.

The condition of the system responding to local inflammation, and termed inflammatory fever, mainly depends on or accompanies the hyperfibrinous state of the blood; and in the words of the philosophical writer we have before quoted, "the greater fibriniferousness of the blood in inflammation represents actions of devitalisation and decay in some albuminous material. Whether this changing material be the inflamed texture gradually dissolving itself in the blood, or be the albumen of the fevered blood itself undergoing accelerated waste, cannot, in the present state of knowledge, be even approximately stated."

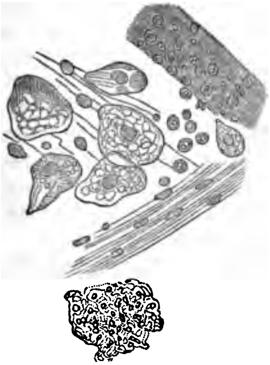
The Results of Inflammation are most varied. I. **Resolution**, to which alone the name of "termination" is applicable. This most favourable occurrence implies the gradual return to the condition of healthy nutrition.—Delitescence, or sudden removal, and metastasis, or translation to a distant part, agree with resolution as far as the part engaged is concerned, for in both it is left in its normal state. II. **Effusion of Serum**, which mostly follows chronic and asthenic inflammation. Fibrin is present in many effusions, which will remain fluid as long as they are contained within the body; but when withdrawn, especially if a portion of solid fibrin be present, that material rapidly fibrillates. III. **Effusion of Blood** occasionally occurs, as in pneumonia, when it colours the sputa; and in chronic cerebritis, when the brain substance is reddened by it. Probably in such cases its colouring matter, and not its cells, is alone present. IV. **Exudation**, which is the essential feature of inflammation. The material exuded is identical with the plasma of the blood, but in pathology it goes by the name of lymph, of which *Paget* describes two varieties, fibrinous and corpuscular; the latter being termed croupous by *Rokitansky*, from the disease in which it is so plentifully effused. *Williams* classifies fibrin as plastic, cacoplastic, and aplastic.

The difference between fibrinous and corpuscular lymph consists in the greater relative number of white-cells in the latter, and the following circumstances determine the production of one or the other: 1. State of the blood; 2. Seat of the inflammation; 3. Degree of the inflammation. The first point is well shown in *Paget's* famous experiment: he applied cantharides blisters to thirty patients in St. Bartholomew's Hospital; and on collecting the serum, he found such differences in microscopical and other characters, as to be able to judge of the disease under which each patient laboured. In sthenic cases, firm fibrinous clots were obtained; in cachetic and phthisical patients, white cells were vastly more abundant, and there were many intermediate degrees. These results explain how various in effect one injury may be to different individuals.

Plastic Lymph is that which is capable of organization ; and in order that this event shall take place, all inflammation must cease, and the conditions which we have before stated as necessary for healthy nutrition must be present. The vessels of the tissue on which it lies bud vessels into it. It may develop into fibrous tissue, as it is most apt to do, or may produce fat, elastic tissue, calcareous matter, true bone, &c. The most important property of organized lymph is its wonderful contraction, from which such changes as the following result : deformed chest after pleurisy, cirrhosed liver, spontaneous amputations in utero, narrowed cardiac valves, distortions after burns, and the stricture of mucous canals with which, as surgeons, we have so often to deal.

Cacoplastic Lymph is exemplified in tubercle, so readily examined in the lung. *Rokitansky* distinguishes the grey and yellow tubercle, but the latter is merely an advanced stage of the former. It at first is laid down in discrete masses, the size of millet seeds (miliary), which project when the lung is cut, as they have less elasticity. The masses then coalesce, and crude tubercle is formed. The colour is like that of cheese, afterwards more yellow and often stained darkly by carbon. The microscope shows a clear blastema, without fibres, granules, and oil particles, chiefly in the yellow and withered and degenerate cells and nuclei. Extraneous matters, such as epithelial and pus cells, fragments of broken down lung tissue, pigmentary and calcareous matter, and cholesterin, are mixed with these constituents. *Virchow* believes the cells are but those of the epithelium of the air-cells, those in the centre being the oldest and largest by imbibition.

Eventually tubercle may wither and dry up, may calcify, or may soften down into pus, which we will presently discuss as an aplastic product; and this being evacuated, a vomica or irregular abscess cavity results. A few pathologists believe it may be absorbed, and *Virchow* thinks this may happen after it has undergone the fatty metamorphosis. The softening generally begins in the centre, which is farther removed from the preservative influence of the blood.



Cacoplastic Lymph. Diphtheritic Exudation.

Another cacoplastic material may be alluded to—the false membrane of that fearful malady, diphtheria. It is described by *Beale*, whose figure is here reproduced, as consisting of a transparent viscid mucus-like material, with wavy lines, entangling epithelial scales, and granular, rounded particles of much smaller size, passing into pus cells in the lower forms of the disease. Acetic acid dissolves the envelope of these cells, as represented in the lower part of the annexed figure, whereas that re-agent makes the cell-wall of pus more evident. That pathologist believes "that the greater part of the epithelial layer is stripped off from the subjacent structure in a membranous form; that this is increased in thickness by the rapid development of new cells, having the characters above described, upon the surface of the mucous membrane; and that these new cells, corresponding to the deepest layer of epithelium, lose more and more the epithelial character, and tend gradually to pass into pus corpuscles." *Virchow* thinks the exudation is into the mucous membrane, which then ulcerates from the tension.

Aplastic Exudation may be conveniently studied in pus. This well-known fluid is of a greenish yellow colour, creamy consistence, and alkaline reaction; has a faint odour and taste, and a specific gravity of 1·020 to 1·040. It consists of cells and liquor puris. The cells, as before stated, cannot be distinguished by the microscope from white blood cells, and are globular, rough, and nebulous, and about $\frac{1}{2500}$ in diameter. The fluid contains albumen, pyin—which differs from albumen in being thrown by acetic acid—and salts similar to those of the plasma of the blood, than which it contains much more fat. Many varieties of pus cannot be distinguished save by their contagious qualities, as syphilitic, gonorrhœal, or variolous; others, as laudable, strumous, ichorous, sanious, sabulous, &c., are known to every hospital student by their physical characters. *Virchow* regards pus cells as the cells of areolar tissue rapidly generated; but, according to other pathologists, pus is but a degenerate form of fibrin, and *Paget* shows that granulations break up into it, their cells becoming pus cells, and the blastema, liquor puris by liquefaction. The formation of an abscess in areolar tissue is described by that great pathologist as follows: A round mass of lymph is poured into this tissue, which it distends and softens. The centre changes into pus first, because it is farther from the vessels which abundantly ramify around the circumference. The most external part of the mass remains solid, and is named the limiting fibrin, cyst, or pyogenic membrane of *Delpech*. The abscess then tends towards the cutaneous or mucous surface by progressive absorption, like other tumours, and not by converting the tissues over it into pus. The skin loosens, the cuticle cracks, and the cutis giving way by ulceration, the pus escapes, and the cavity is obliterated by granulation and contraction. Besides the foregoing circumscribed form of suppuration, the process of diffuse suppuration is seen in pneumonia, when the parenchymatous tissue of the lung, or in phlegmonous erysipelas, when the subcutaneous areolar tissue is soaked with the effused lymph. A third form may be well studied in gonorrhœa, or still better in purulent conjunctivitis, when pus is produced from a mucous surface by the conversion of epithelial cells into pus cells, as *Virchow* has explained.

V. **Ulceration**, or that process by which a superficial part is removed in molecules, was believed by *Hunter* to be but a variety of of absorption, the debris being taken back into the circulation. That, however, the particles are thrown off with the discharge seems more probable, as we find the broken tissue of cartilage cast into the joint, and the particles of bone in caries are found in the pus, rendering it sabulous. This molecular disintegration is only different from mortification in the size of the particles killed, and is not the result of any corrosive property of pus. However, *Rokitansky* believes many ulcers spread by a catalytic action, which unhealthy pus exerts on the surrounding parts. The term ulcer is applied to a sore while it is forming and while it is healing, which result may be attained in the last three methods of cicatrisation we have described in the section on repair.

As cartilages are permanently cellular and lowly vascular, many of the pathological changes we have been discussing are studied in them with great advantage; their absence of nerves likewise proves that the starting point of these changes does not lie in the nervous system, and they have been investigated in a masterly way by an accomplished physiologist and pathologist. For these reasons I shall quote the following conclusions from *Prof. Redfern*, to whose researches I have so often referred:

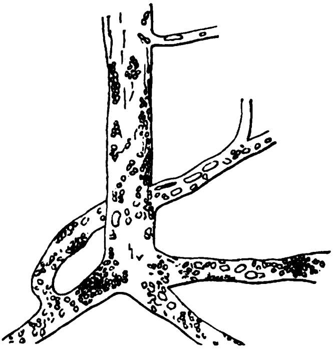
"1st. That the whole of the known forms of disease in articular cartilages are connected with changes in the texture which are essentially similar to each other.—

2nd. That during the progress of these changes the cells of the cartilage become enlarged, rounded, and filled with corpuscles, in lieu of healthy cells; bursting subsequently, and discharging their contents into the texture on the surface; whilst the hyaline substance splits into bands and fibres, the changed hyaline substance and the discharged corpuscles of the cells, afterwards forming, in many cases, a fibro-nucleated membrane on the surface of the diseased cartilage. 3rd. That these changes are alone referable to an anormal nutrition as their immediate cause, and in no case to mechanical or chemical actions, such as attrition or digestion in a diseased secretion. 4th. That most extensive disease may be going on in many joints at the same time, and may proceed to destroy the whole thickness of the cartilage in particular parts without the patient's knowledge, and whilst he is engaged in an active occupation. 5th. That the disease commences most frequently upon the free surface; but it may proceed from the bone to affect the attached surface, or it may take place in the middle of the thickness of the cartilage. 6th. That it is, at least, very doubtful if the symptoms which are believed to indicate the existence of ulceration of articular cartilages, are not really dependent on a morbid change in the bone. 7th. That disease of the whole thickness of an articular cartilage at particular parts admits of a natural cure, by the formation of a fibro-nucleated membrane from the substance of the cartilage, without the occurrence of any new exudation."

VI. **Mortification** is the last and most destructive result of inflammation, for by it the part is killed, and subsequently undergoes the same decomposition as the subject does in the dissecting-room—the life of the body at large still continuing. The dead part is named the sphacelus—or in the case of bone, the sequestrum; the process of necrosis being quite analogous to mortification, save that reparative power is higher and a new bone is formed. The variety which follows inflammation is that termed moist, and it results from the stagnation of the blood in the vessels not being recovered from. This kind of mortification may result from causes not inflammatory; thus, strangulation, as in hernia, kills by preventing circulation; and when the system is enfeebled by cold and intoxication, gangrene of the lung has followed in a few hours without previous inflammation. Most interesting cases of this occurrence were laid before the Pathological Society of Dublin by *Prof. Law*. Severe cold, however, usually kills a part, by setting up rapidly destructive inflammation. When a limb dies after great crushing violence, ligature of an artery, or the sudden pressure of effused blood, inflammation does not always precede its death. Removal of nervous influence promotes the occurrence of mortification. Every surgeon knows how apt paralysed limbs are to suffer from bedsores; and *Sir B. Brodie* saw gangrene attack the foot 24 hours after injury of the spine. Emboli, when they suddenly and completely obstruct an artery, give rise to humid gangrene—or, in the case of the brain, to what is known as "ramollisement blanc." When the calibre of an artery is more slowly diminished, as by calcification, or by the ingestion of spurred rye acting on its muscular coat, dry gangrene is the form which follows; and as the former change is always one of old age, the term senile is often applied. The description of the symptoms of these cases belongs to surgical treatises.

Fatty Degeneration is a most common pathological occurrence, and there is no tissue which may not be its seat—even the serum of the blood may be loaded with fat assuming the chylous character before noticed. Fat may be recognised by its solubility in ether, and by leaving a greasy, inflammable stain on paper. It is a change which often succeeds when parts like the thymus gland, testis, or mamma have ceased to fulfil any function; and the placenta shortly before parturition, and the uterus after delivery, are especially subject to it. Some of the placental vessels in this condition, from a case where apoplectic clots and a putrid fœtus were found, are here represented. Muscles are perhaps more frequently the seat of this process than any other tissue; it was formerly supposed that the sarcous element was removed, and fat afterwards laid down; but *Quain* has proved that the syntonin is actually changed into adipocere, the nitrogen being set free as ammonia. This chemical change can be accomplished artificially if muscle be steeped for a few hours in a weak solution of nitric acid, or if placed in a running stream for some days. If animals be fattened to a high degree, fat cells form in abundance between the fibres. In the voluntary muscles, disuse, or the paralysed condition, is the most frequent cause; but in the heart, which is the only involuntary muscle often attacked, phthisis is a usual concomitant; and, as *Canton* pointed out, the arcus senilis of the cornea often indicates its occurrence. In this organ, the deposit on the surface must be distinguished from the real interstitial change, which is much less frequent.

Fatty Degeneration of Placental Vessels.



Fatty Deposit in Cerebral Arteries.

Atheroma, so common a deposit in arteries, is a fatty matter, partly cholesterin, and sometimes mixed with calcareous salts. The arteries of the brain are especially prone to it, and one from a softened corpus striatum is depicted on previous page. As we might expect from its cellular nature, cartilage often undergoes this degeneration, which, indeed, is the first step in its destruction. The most usual causes of the morbid process is the excessive use of hydro-carbonaceous food and alcohol, and insufficient exercise. It may result also from inflammatory action in some tisues.

In muscle, *Simon* describes the inflammatory and fatty change as follows: "There is mixed, even from an early date in the inflammation, a noticeable quantity of oil drops; that often these oil drops appear before the disintegration of muscle has made much progress, and then arrange themselves in such mutual relation—transverse or longitudinal—as to suggest that the sarcous elements have changed themselves, particle by particle, into oil; that, little by little, the oil drops multiply to such an extent as to be the chief visible objects; the limitary membrane of a fasciculus seeming now to be almost filled with finely divided oil, diffused through some scanty connective albuminous material; that the limitary membrane, within which the muscular tissue is thus emulsionized, tends also itself to undergo dissolution, and let its proceeds confuse themselves with the similar debris of neighbouring fasciculi, till more or less bulk of muscle is reduced to a state of oleo-albuminous liquidity."

Fatty degeneration is occasionally combined with an increase in size and number of the fat-cells in the subcutaneus areolar tissue, omentum, &c., which is termed polysarcia, or obesity. In some such cases the body has attained the weight of 36 stone, and in one case recorded the heart weighed 22 oz. The following engravings, from a valuable paper on fatty degeneration by *Mr.*

Richardson, in the 22nd volume of the "Dublin Journal," illustrate the microscopic appearance of hepatic cells when loaded with oil. The first are from the enlarged fatty liver of phthisis, the second from a shrivelled cirrhosed liver. Fatty casts of uriniferous tubes have been described at p. 225, and illustrated by woodcuts after the same able miscroscopist. In the next figures are seen fibrillæ of the heart in a state of fatty degeneration,

Fatty Hepatic Cells in Phthisical Liver.

Hepatic Cells from Cirrhosed Liver.

Fatty Fibrillæ, and one Healthy Fibrilla from Heart.

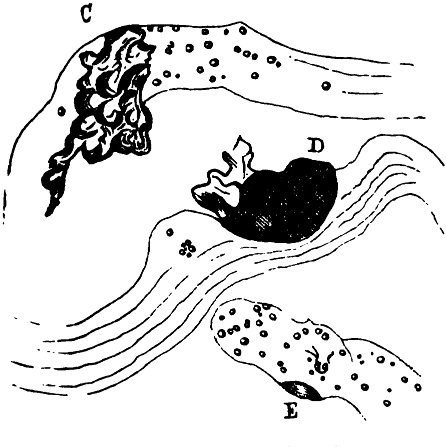
Fibres from Fatty Heart; striæ absent; oil particles deposited.

and in contrast, then, a healthy fibre is shown. The prevention and cure of this pathological condition will be found pretty fully discussed in my "Lectures on Public Health."

Amyloid Degeneration is the name given by *Virchow* to a product which has been also described as lardaceous, waxy, or albuminoid in various organs. It either occurs in separate masses (corpora amylacea), as in the brain, or infiltrated into organs. In the former case its starchy nature is shown by the blue tint which it gives with iodine, but in the latter case the action of that reagent on the albuminoids, and the colour of the organs themselves, renders this test obscure. If sulphuric acid is carefully added to the tissue, a violet or blue colour appears. The spleen, lymphatic glands, liver, kidneys, muscle, and cartilage may undergo this degeneration. Many prostatic concretions are of a similar nature, and are laminated. The muscular tissue of the smaller arteries of various organs are the primary seat of the deposit, and *Virchow* has seen cases where not a single minute artery of the digestive tract from mouth to anus was free from it. It narrows their calibre so much that the parts always have a pale anemic appearance. *Busk* discovered that some of the amyloid bodies had the microscopical characters of wheat-starch, others more closely correspond to potato-starch.

Pigmentary Degeneration is described by many authors, but most of the instances adduced are cases where the tissues or some new formations are stained red, yellow, green, or brown by hæmatin, or the colouring matter of the bile which is derived from it. When the skin was stained of the last-named tint, *Addison* asserted that disease of the suprarenals always co-existed. Black pigment is very common, and the peculiar form of cancer, named melanosis, is very generally believed to be but other varieties dyed with such matter. In the lungs "spurious melanosis" is usually due to the inhalation, in smoke-infested cities or ill-ventilated mines, of carbonaceous matter in a finely pulverised state, which may be distinguished from any pigment derived from the blood by not being decolorised by chlorine.

Calcareous Degeneration is most frequent in arteries and in new formations, especially tubercle. In arteries this deposit lies between the inner and middle coats, and is arranged as minute corpuscles grouped together, presenting no resemblance to the structure of bone, from which it differs chemically in the much greater proportion of carbonate of lime. Nerve cells and tubes have been so calcified that they would preserve their shape when strongly heated, and effervesce on the addition of acid. Its origin in arteries is due to a chronic form of arteritis, save in senile cases, where it lies in the muscular tissue of the vessel, and has more the characters of bone. Blood-clots may also calcify, and many phlebolithes are so produced. The foregoing figures were drawn from a



Calcareous Degeneration of Placental Vessels—fœtus dead.

preparation by *Mr. Richardson*, and represent calcareous degeneration of the placental vessels, which obstetric writers have shown is a frequent cause of the death of the fœtus.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Give a few examples of normal and abnormal atrophy.

2. Is repair more active in the lower or higher animals—the highly vascular or lowly vascular tissues, and give examples?

3. Describe granulations, and the process by which they form a scar.

4. Sketch the forms of callus which unite the femur of an adult or of a child if broken.

5. What proofs can you offer of the enlargement of arteries and capillaries in inflammation?

6. Give the divisions of lymph, and some examples of its contracting power.

7. Describe the microscopical appearances of diphtheritic exudation.

8. Explain a few of the pathological causes of humid and dry gangrene.

9. Enumerate the varieties of degeneration, and give a few examples of normal and abnormal instances of the most frequent kind.

SENIOR.

1. Sketch out a classification of abnormal nutritive changes.

2. What is *Virchow's* division of hypertrophies, and what conditions are promotive of them?

3. Enumerate five kinds of cicatrization, and a few surgical cases where the third is more desirable than the first or second.

4. Describe "scabbing," and the modes of imitating it in the treatment of ulcers.

5. Sketch the modes of union in a divided muscle, tendon, nerve, and artery.

6. Describe the changes in the blood by inflammation.

7. Mention the results of inflammation, and what circumstances determine each.

8. Describe healthy pus and a few of its commoner varieties.

9. Enumerate the theories of ulceration, and describe the process in cartilages according to *Redfern*.

TUMOURS

Are outgrowths which differ from hypertrophies in never serving any useful purpose. This difference may be illustrated by the uterus, which hypertrophies during gestation, but often forms a tumour of exactly similar tissue to its own, often described as polypus. Tumours are usually divided into benign and malignant, the latter class including cancer alone; and with these two subdivisions the terms analogous and heterologous correspond. These epithets are convenient but not strictly accurate. They are also talked of as "continuous" when formed amidst tissue like themselves; "discontinuous" when isolated by other structures. *Paget's* classification is as follows:

I. Cystic tumours—

A. SIMPLE OR BARREN.

1. Serous,
2. Synovial,
3. Mucous,
4. Sanguineous,
5. Oily,
6. Colloid,
7. Seminal.

B. COMPOUND OR PROLIFEROUS.

1. Complex cystic,
2. With glandular or other vascular growths,
3. Cutaneous,
4. Dentigerous.

II. Solid tumours and outgrowths—

1. Fatty,
2. Fibro-cellular,
3. Fibrous, fibro-muscular, fibro-elastic, &c.,
4. Cartilaginous,
5. Myeloid,
6. Osseous,
7. Glandular,
8. Vascular.

1. **Serous** cysts, which occur in any part of the body where areolar tissue exists; for from the cells of this, or perhaps its areolæ, they have their origin. The cyst is lined with tesselated epithelium, and filled with a fluid usually like the serum of the blood; but it may be stained of different tints by its hæmatin, may contain some of its solids, frequently cholesterin, and may be-

come solid on removal, owing to the presence of fibrin. No better example could be adduced than "hydrocele of the neck," as described by *O'Beirne*. 2. **Synovial** cysts, which are either enlargements of original bursæ ("housemaid's knee"), formation of new ones ("bunions"), or distension of the cells of synovial sheaths about tendons (ganglion). They contain synovia, albumen being more abundant in the latter case, and little cartilaginous bodies, like melon seeds or half-boiled rice, are often found within them, especially about the wrist. 3. **Mucous** cysts result from the distension of a mucous cavity or cœcal gland-duct, consequent on obstruction of its orifice. Ranula is an example. 4. **Saguineous** cysts most resemble the serous, save that they are filled with blood, which is either poured out as the result of injury to a cyst previously containing serum, or the enlargement of a vessel in a nævus. One the size of a goose-egg, in the posterior-inferior triangle of the neck, was lately treated by my colleague, *Dr. Quinlan*, in St. Vincent's Hospital. 5. **Oily** cysts are very rare, but have been found connected with the sebaceous or lactiferous ducts, and filled with pure oil. 6. **Colloid** cysts occasionally occur in the kidney or thyroid, and contain a jelly-like matter very similar to that found in the cells of colloid cancer; and 64 parts of albumen per 1,000 may be obtained from such matter. 7. **Seminal** cysts, or "encysted hydroceles," are, as was explained by *Müller*, most commonly distensions of that tubular remains of the Wolffian body which lies above the epididymus, and which is sometimes named "the organ of *Giraldés*." They are by others supposed to be dilatations after obstruction of the seminal ducts, or effusions of fluid between the albugineal and serous layers. They, however, contain spermatozoa, which *Paget* believes they themselves generate; he mentions one which held 46 ozs. of fluid.

Compound or Proliferous Cysts have the power of producing within themselves organised structures. 1.

Complex cystic, which usually grow in the ovary and generate within the parent cyst several others—often in hundreds, and, within these again, often tertiary cysts. *Beale* has found the epithelium occasionally ciliated. 2. Cysts with glandular or other vascular growths are exemplified in the "sero-cystic sarcoma," which *Brodie* described in the breast. The vascular mass produced in the interior may so completely fill the sac as to produce an almost solid tumour, which, according to *Hodgkin*, were always formed in this way originally from a cyst. Still further urging outwards, it may burst the skin and protrude as a fungous mass. This intracystic mass may be glandular, corresponding to the gland with which it is connected, or may be composed of cellular matter much resembling granulations. No tumours are more difficult to diagnose from cancer. 3. Cutaneous cysts produce within them various matters which are normally connected with the skin—they may be congenital or formed after birth. Congenital ones are scarcely ever found except near the eyebrow, often dipping deep into the orbit, and containing fatty matter and ill-developed hairs with the free ends split into many fibres. Of those formed after birth the scalp is by far the most frequent seat, and here they are familiarly known as "wens." *Sir A. Cooper* looked on these as obstructed sebaceous follicles, and believed a dark mark always indicated the original duct. Tablets of cholesterin are often present, and may be tested by giving a blue tint, passing to brown, with iodine and sulphuric acid. Cysts containing cutaneous matters may occur in the ovary, where they generate these contents very perfectly; so that at one time they were supposed to be the remains of a partly absorbed fœtus: they have been also occasionally observed in the testis, kidney, and even within the skull. It is remarkable that there is a strong hereditary tendency to their production. 4. Dentigerous cysts occur mostly in the ovary, or may be congenitally formed in other situations. Teeth, even to the number of 400, have been found within them, and occasionally also hair, epidermis, &c. Those occurring about the jaws are tooth saccules, from which the teeth were never protruded.

II. **Solid Tumours and Out-growths.**—1. **Fatty** tumours are likewise known as lipoma and steatoma. Those which are continuous occur in the subcutaneous fatty tissue, of which they are a local increase, and are well distinguished by their scalloped edge, projecting into the surrounding areolar tissue, and their soft "pillowy" feel. Others may occur even where no adipose tissue normally exists, and are covered with a capsule which dips into and lobulates the fatty mass. These are known by the skin over them dimpling when squeezed. The microscope discovers fat-cells larger than normal, especially in the softer tumours; others of them are shrivelled and some occasionally contain beautiful crystals of the fatty acids.

2. **Fibro-cellular** tumours, which consist of areolar tissue usually in a distended or dropsical state, owing to the pendulous form most of these out-growths possess. Of these covered by mucous membrane, simple polypi, as those of the nose, rectum, or bladder, are good examples; and they have a ciliated, columnar, or tesselated epithelium, according to the situation from which they spring.

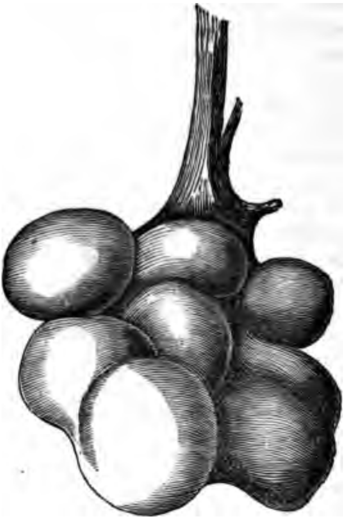
Dr. O'Ferrall published, in 1847 ("Dublin Journal"), a masterly account of pendulous tumours which he had observed in St. Vincent's Hospital and in consulting practice. I shall quote his description of the appearances on section, and refer to his memoir, which contains all we know on the history, diagnosis, and treatment of these important growths: "The general appearance of the section of pendulous tumours is that of areolar tissue, more or less hypertrophied, and containing in its meshes a limpid secretion. The whole has a pearly or whitish semi-transparent appearance, when of the simplest kind. In the living state this section would, no doubt, be more or less vascular, and present a very different hue. The granulations which spring from these tumours, when the skin has given way, have invariably the red, fleshy tint of a highly organized part. To the tissues already named, and which constitute the simplest form of pendulous tumour, may be added others, which give it a special character. Thus the cellular tissue may contain adipose substance in quantity sufficient to give it the character of a fatty tumour. I have seen several examples of this kind, and shall relate the particulars of the most remarkable instances further on. The cellular tissue may be occasionally the basis of an accidental erectile formation. The tumour in such cases has the uneven purple colour of the nævus, and is capable of great reduction in its volume when compressed between the fingers. A section of these tumours shows the numerous apertures of vessels divided in different directions with respect to their axes."

Fibro-cellular tumours often occur about the labia or scrotum, and have been mistaken for elephantiasis of those parts; but they are more discontinuous, and are separated and lobulated by firm areolar tissue. Elephantiasis is more painful, fissured and excoriated, and is produced by recurring attacks of erythematous inflammation. Such tumours yield gelatin, and albumen from the serum which soaks them, on analysis. They have no malignancy. *Dr. Beatty* and I removed a large one from the left labium of a lady two years since; six months after she was found to labour under scirrhus of of the os uteri, but the scar of the operation remained still perfectly healthy. 3. **Fibrous** tumours consist of white fibrous tissue, often glistening and tendinous. The fibrous polypus of the uterus is the type of such outgrowths in most particulars; but as its tissue is identical with that of the womb itself, the term fibro-muscular would be more correct. Somewhat similar ones may project from the nose or pharynx, and "discontinuous fibrous" tumours occur pretty often about the jaws, including some forms of epulis in nerves, the testicle, &c. *Mr. Paget* has seen their cut surface rise up into prominences, like those which form on section of an intervertebral disc. They have been known to undergo the calcareous degeneration. Their weight is often enormous, having attained 71 ℔. 4. **Cartilaginous** tumour, or enchondroma, as *Müller* named it, is frequent on bones, and occasionally occurs in the testis, parotid, mamma, &c. In 35 cases the relative frequency was: bones of hand, 26; tibia, 3; testis, 2; ilium, 1; cranium, 1; ribs, 1; parotid, 1. They are usually rounded, hard, but elastic on firm pressure, covered in such places as the testis with a tough fibrous capsule—or in bone, by a thin osseous shell. Section produces the well known screeching sound of gristle. Their microscopical appearances are most varied, but most usually are those of infantile cartilage, sometimes with ossific specs or fibrous tissue mingled. They yield chondrin. The largest ever known was that described by *Sir P. Crampton*, which measured 6½ feet in circumference and grew from the thigh bone. When softened, their cells much resemble cancer cells; but acetic acid distinguishes the cell wall and nucleus of the latter—not the former. 5. **Myeloid**, or marrow-like tumours, were first accurately described by *Paget*. They are found in or on bones, more often the former, in which they differ from the cases last described. Their consistence and appearance on section are described by him as follows: "When not encased in bone, they usually feel firm, compressible, slowly resilient, and 'fleshy;' very few are harder than these words imply; but some are much softer, easily broken, like ordinary granulations. On section, their most frequent appearance is that of an uniform greyish or yellowish shining substance, blotched or suffused with deep crimson or pink, or blood-colour. The range of varieties of appearance is very wide; and besides, partial ossification, with plates or bars of bone intersecting the tumour, is not rare; and cysts filled with serous or bloody fluids are, in the instances of large myeloid tumours, frequent." From the presence of many spindle-shaped fibre-cells, *Lebert* alluded to these tumours as "fibro-plastic;" but their most characteristic elements are large corpuscles ($\frac{1}{300}$ to $\frac{1}{1000}$), with numerous nuclei, such as occur in fœtal marrow or diploe. Some forms of epulis are myeloid.

6. **Osseous** tumours may be divided, like bone tissue, into cancellous and compact. The former are always developed as cartilage, contain marrow-like matter, and are covered with a thin shell of harder bone. The ivory-like form is much smaller, and seldom occurs but on the outer surface, or in the diploe of the cranial bones, where it may produce most serious effects by pressing into the cavity. They are not usually cartilaginous at any period of their growth, but *Prof. Goodsir* mentions one of the humerus, half of which is cartilage and half ivory-like bone. Others have been found growing from the inner table, chiefly in puerperal women. Osseous tumours have canaliculi and lacunæ, while, on the contrary, calcareous degenerations, before described, are amorphous.

7. **Glandular** tumours, or adenoid, as they have been termed by *Velpeau*, may be formed of tissue, like the ductless or the secreting glands. Of the former, small masses which grow near the thyroid are the only examples, for bronchocele and the enlarged state of the ductless glands which accompanies leucocythemia are hypertrophies—not tumours. The secreting glands, which are occasionally imitated by tumours growing in or near them, are the mamma, prostate, parotid, and labial glands. The first, the "chronic mammary tumour" of *Sir A. Cooper*, is the only one invested with

surgical importance, by its frequency. They are usually lobed, as seen in the annexed representation of a case by *Mr. Richardson*, and microscopically they are very similar to the milk-secreting tissue in a rudimental form, like that of the male breast, as *Birkett* remarks. They may undergo reduction or absorption, especially if the function of the gland is called into action.



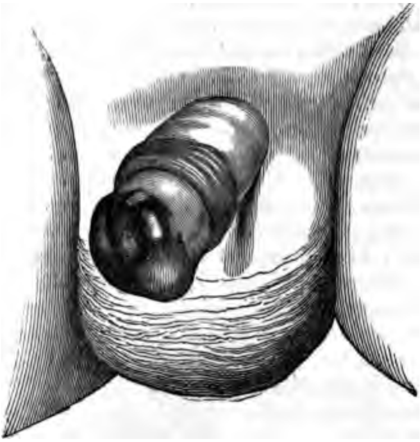
The Chronic Mammary or Adenoid Tumour.

In the late *Mr. Colles*' "Surgical Anatomy," 1811, I find so admirable an account of the tumour that I cannot forbear quoting part of it, as one of the pathological subjects which the unequalled powers of observation of that great surgeon displayed: "This is a distinct tumour or hardness in the breast, generally seated deep in the substance of this gland, and towards the axilla. This is usually traced by the patient to some slight hurt. In size, it scarcely ever exceeds a walnut. Its surface seems rough; but this is caused by its being felt through the gland. It is occasionally attended with some slight pains; these are induced by any distress of mind, by wearing the clothes tight across the breast, and by a costive state of the bowels. On the approach of the menstrual period these pains increase, and cease on this evacuation being completed. A temporary enlargement of the tumour attends these attacks of pain, and retires on their cessation. The subjects of this complaint are young women, generally under thirty years of age. In one instance, the patient was nearly forty years old, and unmarried; in another, the lady was married, but had not any children, and was irregular in menstruation. These tumours disappeared in such of these patients as became nurses, and in the others have remained stationary for many years."

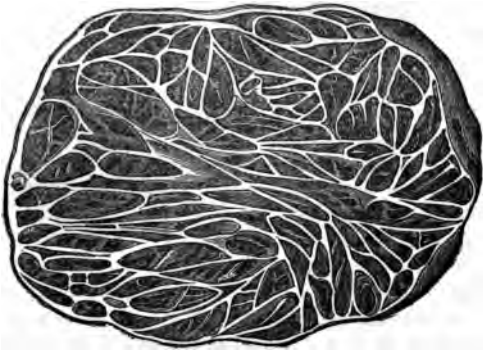
8. **Vascular Tumours** are composed of dilated arteries, capillaries, or veins; or, in some cases, all three kinds of vessels are engaged. Their most frequent seat is in, or under, the skin (a most important distinction, as regards surgical treatment), where they are termed "nævi;" but they have been found in the liver, brain, bones (osteo-aneurism of *Handyside*), and may probably form in any tissue which vessels penetrate, of which I have recorded an instance in the "Medical Press," for February,

Erectile Tumour of the Glans Penis.

1863. The gentleman remained well after the operation. In the same journal for January, 1864, will be found an account of a vascular tumour which grew from the glans penis; and *Mr. Richardson* recorded also a similar case.



Congenital Erectile Tumour of Glans Penis (Mr. Richardson).



Section of Erectile Tumour.

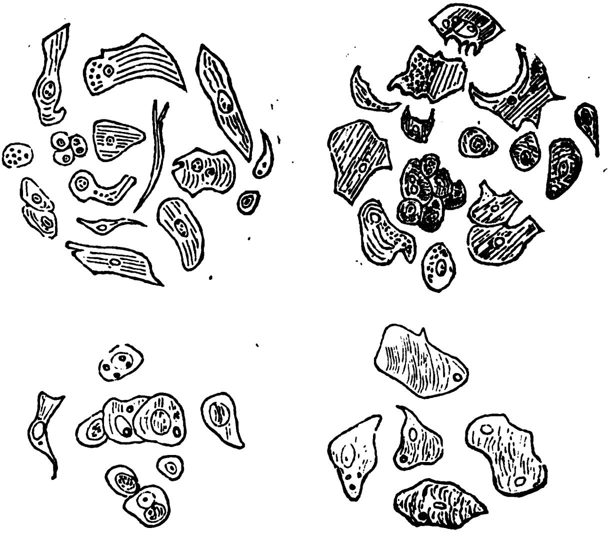
The appearances of these tumours are represented in the foregoing engravings, and the microscopical characters of vascular tumours is well seen in the following section, after *Paget*. They are usually soft, emptying and becoming pale by pressure; filling and becoming turgid, like erectile tissue, when the circulation is excited—but they may harden with clots of blood, phlebolites, &c. They are usually congenital; but, besides the instance I have mentioned, *Warren* describes one which grew about the eyelids in a girl 17 years old. *Sir R. Carswell* believed they often depended on atony of the vessels throughout the system, for he has found large arteries, as the iliacs, tortuous and distended in many of these cases.

Neuroma, or a swelling on a nerve, may be alluded to. We owe nearly all our knowledge on the subject to the treatise of *Prof. R. W. Smith*, which is the most exhaustive and most splendidly illustrated monograph ever published upon any disease. One form, "the painful sub-cutaneous tumour," was described and so named by *Wood*, in 1812.

Before commencing the next division of morbid growths, there is a class of tumours which are supposed to hold an intermediate place between innocent and malignant diseases, as the terms "semi-malignant" and "recurrent" indicate. There is a growing tendency, however, among pathologists to consider cancer as something not entirely distinct from the normal constituents of the body. This view is expressed by *Mr. M. H. Collis*, of the Meath Hospital, in the following formula: "The nearer in form and power of development that the constituent cells of a tumour are to the healthy lymph-cell, the more innocent is the tumour; the further removed, the more destructive."—("Dub. Quart. Journ.," Nov., 1860).

The tumours which are most apt to return are those which combine the characters of the fibrous and fibro-cellular—hence they are described by *Paget* as "recurring fibroid;" but any class of tumour may possess this character, in which alone they differ from more innocent examples of the same type. This unrivalled pathologist, in his latest work ("Tumours—Holmes' System of Surgery"), says: "The general appearance of recurrent tumours is, in their first growth, often not distinguishable from that of tumours of the same structure that are not likely to recur; they may look like ordinary fibro-cellular, fibrous, or other tumours. More often, however, they differ from these ordinary tumours in that they are softer, more succulent or glutinous, glistening or translucent, brittle or easily torn, with a kind of fibrous grain. Commonly all these peculiarities become more marked in the successive recurrences of the tumour; and the later growths are generally like masses of yellow or ruddy soft gelatine, with blood-vessels. The later are, also, usually much more rapid in their progress than the earlier growths, and are generally less well-defined, penetrating further and more vaguely among the interstices of adjacent parts, and more quickly protruding through the skin or scars over them. The likeness of recurrent tumours to cancers, in many of these points, is evident. But their unlikeness is as distinct. They rarely look like cancers to the naked eye—never to that assisted with the microscope; their homology with the natural structures, though in a rudimental, and, it may be, degenerate state, is clear. They do not affect the lymphatics; their recurrence is *in loco;* and in the few cases in which, late in the disease, similar growths have occurred in the lungs, it may be suspected that the propagation was by direct carrying of germs with the blood from vessels into which a tumour had grown—as in the case of cartilaginous growth in the testicle. Moreover, after repeated recurrences, the patient commonly retains apparently good health, and shows none of that cachexia which would almost certainly exist in a patient who had suffered repeated recurrences of cancer."

In the same debatable ground may be placed the morbid growths named Epithelioma by *Hannover*. The cells of epithelium and epidermis are constantly being shed and replaced by new ones; but, if generated in increased numbers by some morbid physiological stimulus, or if their exuviation be prevented, they give rise to tumours.



Cells of Epithelioma.

Warts and condylomata, which grow from mucous surfaces, or where sebaceous follicles abound in skin, are also, however, papilla-like masses of such cells, with a capillary looping into each projection. Those which occur round the anus, the mucous tubercle, or "plaque muqueuse" of *Ricord*, are syphilitic, and some believe contagious.

The common epithelial tumour of the lower lip, or that of the cervix uteri, mainly consists of epithelial cells of various sizes and degrees of formation. Sometimes, deep in the mass, large circular spaces filled with cells may be found, and they are termed "cell-nests." Some may measure $\frac{1}{300}$, and as they seem to generate other cells by endogenous growth, are named "brood-cells." In others the cells are more intimately infiltrated into the tissues. It is remarkable that men are more subject to this disease in the proportion of 86 to 19. The foregoing representations of the cells of Epithelioma are from *Mr. Richardson's* paper in "The Dublin Hospital Gazette." Some growths from mucous surfaces, often termed "villous cancer," are of this papillary nature, as also is the "cauliflower" excrescence of obstetric writers. *Paget*, who regards epithelial tumors as cancerous, sums up his reasons for that view as follows; and from their consideration, and a careful microscopical examination of one which grew on the left tonsil of a patient of mine, I am inclined to coincide in them to the fullest extent:

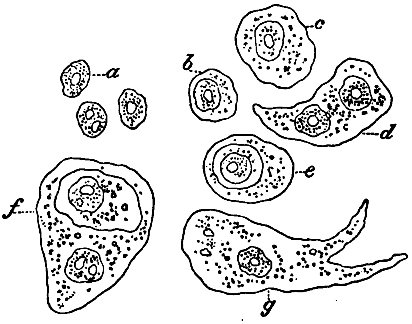
"1. The interstitial formation of structures like those of epithelium is not an imitation of any natural tissue; it constitutes an heterologous structure—for superficial position is more essential to the type of epithelial structures than any shape of elemental cells or scales is. 2. Even that delusive appearance of homology which exists when the structures like those of epithelium are formed in the dermal tissues, and therefore near the surface, is lost in nearly all the cases of deep-seated epithelial cancers, and in all the similar affections of the lymphatic glands and internal organs. 3. The interstitial formation of cells in epithelial cancer is conformed with the characteristic plan of all cancerous infiltrations, and leads to a similar substitution of new structures in the place of the original tissues of the affected part. 4. The interstitially formed cells often deviate very widely from the type of any natural epithelial cell, in shape, in general aspect, in method of arrangement, and in endogenous formation. The difference between them and any natural elemental structures is, indeed, much greater than that between many medullary and schirrhous cancer-cells and the cells of the organ in which they grow: *e. g.* it is sometimes difficult to distinguish the cells of a medullary cancer in the liver from those of the liver itself. 5. The pathology of epithelial cancers is scarcely less conformed than is their anatomy to the type represented by the schirrhous and medullary cancers; for, not only are they prone to incurable ulceration, and to repeated recurrence after removal, but (which is much more characteristic) they usually lead to the formation of structures like themselves in the lymphatic glands connected with their primary seat, and they lead sometimes to similar formations in more distant organs. 6. In their growth, and in their recurrence, there is no tissue which the epithelial cancers do not invade and destroy. 7. A peculiar liability to them seems to exist in certain members of those families in which schirrhous or medullary cancers also occur."

CANCER,

Is a term which properly includes the following varieties of malignant disease, for they are all distinguished by the character from which this ancient name is derived—namely, that of spreading and infiltrating into all tissues:

I. Scirrhus, of which the disease affecting the mamma may be taken as the type. It is a heavy, hard, inelastic mass, often as firm as fibro-cartilage, and in size never exceeds the normal size of the portion of the breast it attacks. It is infiltrated as intimately into the organ as lymph is in pneumonia, and has no capsule. When firmly pressed, a "juice" exudes; and the dry fibrous matter which is left is termed the "stroma"—a structure not proper to the cancer, being only the areolar tissue of the part; thus, for instance, if schirrus is deposited in the brain, the so-called stroma is absent, as there is little or no areolar tissue in this place normally. *Rokitansky*, however, believes the stroma an essential element, and that the only difference between scirrhus and encephaloid cancer is, that the one has more stroma, the other more cells. A very characteristic appearance on section is, that the cut surface becomes concave, and it is a light grey colour, mixed with gland tissue, which however, as well as the fat, rapidly wastes.

When a little of the juice is placed in the field of the microscope, "cancer-cells" appear in numbers and most diverse forms—which multiformity is, however, very characteristic. Their shape may be rounded, pyriform, or bifid, and their diameter ranges from $\frac{1}{700}$ to $\frac{1}{1500}$. The fundamental and most reliable element is the nucleus, which may be either free or included, one, two, or three, within the cell; it is commonly about $\frac{1}{2500}$, and has one or two bright nucleoli within it. Some of the most usual forms are here sketched.

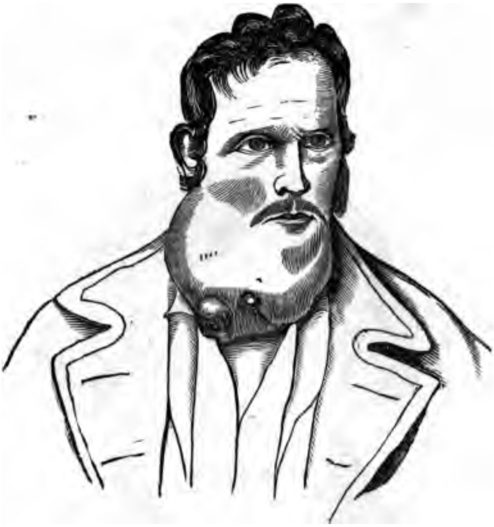


a. Free nuclei.
b. Small cancer cell.
c. Larger cell.
d. Cell with two nuclei.
e. Mother cell.
f. Mother cell, enclosing a simple nucleus and a nucleated cell.
g. Large irregular and bifurcated cancer-cell.

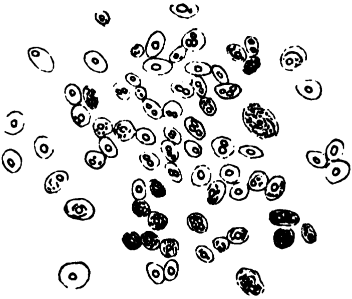
Microscopic characters of Scirrhus—(*magnified* 460 *diameters*.)

II. **Encephaloid Cancer**, as *Laennec* termed it, from its very complete resemblance to the brain, has also been known as fungus hematodes (*Hey*), medullary sarcoma

(*Sir A. Cooper*), soft cancer, acute cancer, and many other terms. The testis is the most frequent seat (30 per cent.), but the eye, bones, uterus, &c., are occasion-

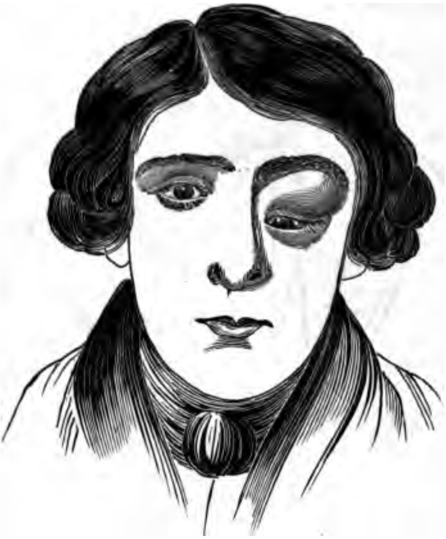


Encephaloid Cancer.



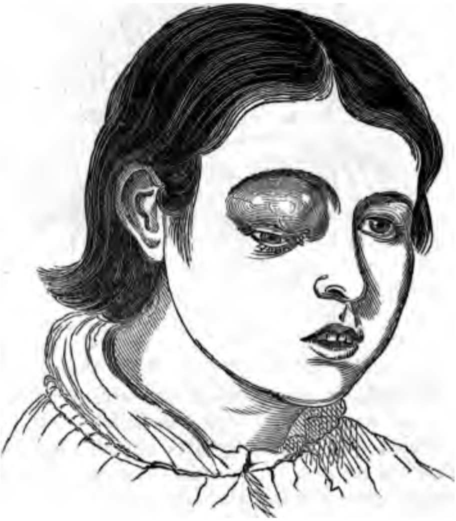
The Cells of Encephaloid Cancer.

ally infiltrated with it. The external characters of the tumour, and the size it may attain, can be judged of from the foregoing sketch of a patient of *Mr. Richardson's* in the Adelaide Hospital. The resemblance to brain is lost in some of the more vascular form, when it looks more like the soft, spongy tissue of the placenta; and in such cases, during life, pressure on the main artery will often fail in arresting hemorrhage. Lymphatics have been traced into the mass. The cells which are figured on p. 475 are very like those of scirrhus, save that they are larger, softer, arranged more loosely, and more easily altered by water. The mass is very apt to soften and break up, or undergo "saniation," as *Rokitansky* terms it. The special place where the diseased material is laid



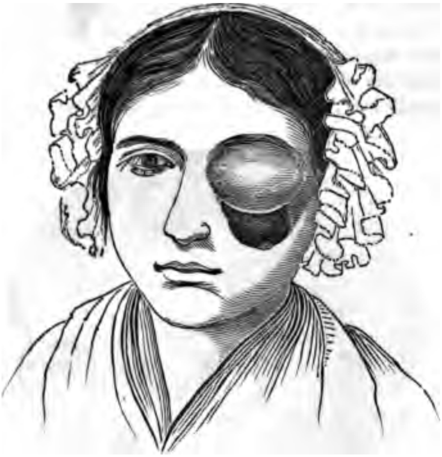
Encephaloid Tumour in Orbit.

down gives special characters to the tumour; thus, for instance, it has a hard skeleton in bone, or is firm and unyielding in the testis, as the albugineal coats firmly encapsulates it. The exact anatomical position of encephaloid masses is so important, when the propriety of removal or the method of operation comes to be discussed, that I shall illustrate the relations which such tumours



Encephaloid Cancer.

in the orbit possess to the tunica vaginalis oculi by three of the figures from *Dr. O'Ferrall's* well-known lectures, in the second volume of the "Dublin Hospital Gazette," 1846. The first lay above the fibrous investment of the eye-ball, in the situation of the lacrymal gland; the second was loose in the adipose tissue above the tunic of the muscles; and the third, growing from the orbital periosteum, extruded the eye-ball, and rendered its removal advisable.



Orbital Tumour extruding the eye-ball.

III. **Colloid**, or glue-like—a term also applied by *Laennec*, and synonymous with gelatiniform—refers to a cancer which most generally attacks the stomach and other internal organs. The naked eye perceives, when it is cut, spaces often the size of a pea or nut, or even an inch wide, partitioned by areolar tissue and filled with the clear colloid matter—so that *Paget* regards it as a cystic degeneration of scirrhus. The glue-like matter is insoluble in water, and contains but 7 per cent. of nitrogen, thus differing from gelatin. Colloid cancer is usually considered secondary when found in the omentum. My friend, *Prof. Foster*, of Queen's College, Birmingham, however, has lately published an interesting example of the primary deposit. He describes its microscopical characters as follows: "The structure of the tumour possessed a distinct capsule, to which I have alluded above. This is rarely found in colloid tumours, except in the omentum. The smaller nodules on the bladder and elsewhere did not possess any very distinct capsule. When examined under the microscope, sections of the tumour exhibited the nucleated cells, called colloid corpuscles by *Lebert*. Large compound cells were also observed, containing several granular nuclei of various sizes, as well as nucleated cells. The fibrous tissue was also distinctly seen."

Melanosis need scarcely be referred to as a separate form of cancer, for *Carswell* demonstrated that it was but any other form stained accidentally by pigment; thus, in the lungs, eye, skin, &c., it most frequently occurs, for they normally contain pigment.

As regards the nature of cancer much uncertainty prevails, some modern pathologists believing that its germs or nuclei are carried in the blood (cancremia), others that it is only a local perverted nutrition. It is only in the very latest stages, when the cancer is being broken up, that any microscopical or chemical examination discovers any alteration in the blood; then nuclei and other debris, and fibrin to the amount of 17 per 1,000, have been found.

Physical Alterations of texture are frequent results of perverted nutrition, and examples of each kind will be readily remembered. 1. Hardening is often the result of chronic inflammation, as in cirrhosis of the liver, lung, and other organs, or may follow the frequent determination of blood—the ivory-like condition of the inner table of the skull, especially of the insane, is an example. 2. Softening is nearly always a sequence of inflammation, the increased effusion of serum or pus producing the change. That which brain substance undergoes is either of this kind, produced by insufficient supply of blood, or by fatty degeneration, and these three varieties are known respectively as the red, white, and yellow ramollisement. 3. Contraction is most generally the effect of organised lymph, which, when formed in the sub-mucous tissue of canals, produces stricture; and in front of this narrowing the calibre becomes diminished in proportion to the decreased bulk of the matters which pass through it. 4. Dilatation follows the accumulation of contents in hollow organs which become too weak to expel them, and is exemplified in the heart, air-cells, colon, &c. 5, 6, 7. Obstruction, compression, and displacement are mechanical alterations which often result from aneurismal or other tumours, or from great effusions. A well known example, pleural effusion, will so obstruct and compress the lung

Idiopathic Emphysema.

as to deprive it of all air, and will displace the heart far from its normal site. 8. Rupture of the heart may result from excessive action when disease has softened its texture.

I have been tempted to introduce the foregoing illustration of a case, I believe unique—namely, one of general emphysema quite idiopathic—as the child (a patient, some years ago, in the South Eastern Hospital) never received any mechanical injury, or was not the subject of any septic disease.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. How does a tumour differ from an hypertrophy? Mention the two great divisions of them.
2. Mention some contents of proliferous cysts.
3. What benign tumours are hardest after bone? Describe the obvious characters on section.
4. What tissues may be the seat of vascular tumours? Have they been found as outgrowths on a naturally erectile tissue?
5. Mention the frequent seats and microscopical characters of epithelioma.
6. What are the kinds of cancer? Contrast them, and state the most frequent seats of each.
7. Mention a few examples of physical alterations produced in tissues by perverted nutrition.

SENIOR.

1. Enumerate the sub-varieties of cystic and solid tumours.
2. Explain the opinions entertained of the nature of "encysted hydrocele" of the testis, especially that of *Müller*.
3. Under what heads as tumours would you place the common nasal polypus, and the pendulous tumour of *O'Ferrall?*
4. Mention a few adenoid tumours. Who described the most frequent of them first?
5. State the points of resemblance and of difference between recurrent fibroid tumours and cancer.
6. Is it important to ascertain the position of orbital cancerous tumours with respect to the tunica vaginalis oculi?
7. What are the abnormal states of the blood in cancer?

ABNORMAL INNERVATION.

The great subject of the lesions of innervation is so inseparably connected with special pathology, that I must content myself with giving definitions merely of the more important varieties of nervous disorders. Detailed descriptions seem the less necessary as the abnormal nutritive changes we have been just discussing constitute the essence of many lesions heretofore considered peculiarly nervous: for example, *Brown-Sequard* has shown that all forms of paraplegia are either due to an increased or to a decreased quantity of blood in the spinal cord. Our knowledge of the pathology of innervation is not at all commensurate with that of the function of nutrition, but recent advances in the physiology of this system have been already followed by corresponding additions to our knowledge of its morbid changes. When the student has, therefore, mastered the subject of healthy innervation, he will be enabled to study with advantage its diseases, which are fully treated of in the masterly works of *Hughes Bennett*, *Brown-Sequard*, *Russell Reynolds*, and especially in *Romberg's* monograph, translated for the Sydenham Society by *Dr. Sieveking*.

Cerebral diseases constitute the first class of the abnormal states of the nervous centres, and they have their seat in the interior or in the convolutions of the hemispheres. The principal varieties are as follows: 1. Insanity, or unsoundness of mind, which has been subdivided as follows by *Tuke* and *Bucknill:*

Idiocy (including imbecility and cretinism).	
Dementia	Primary and Secondary.
Delusional Insanity ...	Melancholic. Exalted. Destructive.
Emotional Insanity ...	Melancholic. Exalted. Destructive.
Mania	Acute and Chronic.

2. UNCONSCIOUSNESS, which, if characterised by prolonged somnolency, is termed "trance," or, if associated with mental excitement, "ecstasy." 3. APOPLEXY, which may be defined as sudden loss of mental, sensorial, and motorial power dependent on cerebral cause. According to its anatomical nature, apoplexy is either simple or congestive, sanguineous or serous; and according to symptoms, *Abercrombie* divided the disease into primary, non-primary, and paralytic—which latter is popularly known as a "paralytic stroke." Syncope and apnœa present the same nervous conditions as apoplexy, but the heart and lungs are respectively the seats of these pathological states. Narcotic poisons generated in the blood, as urea; or introduced from without, as opium, alcohol, or chloroform—and those agents which produce the condition surgically termed "compression," depressed bone, or effused blood, serum or pus, for examples—give rise to coma, which is not always readily distinguishable from apoplexy. Saltatory movements, tremors, perverted ideas, delirium, somnambulism, prostration by fright or surprise, vertigo, head-ache, feelings of lightness or heaviness, &c., are nervous symptoms which cannot be connected with any positive pathological state.

II. **Spinal** diseases, in which both the cord and its intra-cranial prolongation are engaged, their functions being either decreased, increased, or perverted. 1. IRRITATION—indicated by hyperæsthesia, or increased sensibility or pressure along the vertebral column, "often associated with a variety of neuralgic, convulsive, spasmodic, or paralytic disorders, affecting, in different cases, all the organs and viscera of the body, and so giving rise to an endless number of morbid states" (*Bennett*). 2. HYSTERIA—a combination of mental, sensorial, or motorial symptoms, occurring paroxysmally, imitating almost every known disease, and which is probably connected with uterine malady. 3. CHOREA—irregular clonic convulsions of the muscles of the face and limbs especially, occurring wholly or partly beyond voluntary control, and increasing in violence if predetermined associated movements are attempted. 4. CONVULSIONS—tonic or clonic spasms of the muscles, usually of a reflex character, and therefore considered as centric spinal diseases by *Marshall Hall*. 5. TETANUS—tonic spasm of the voluntary muscles, and especially of those of respiration. The following terms are applied to the disease according to the part of the body affected: trismus, if the masticatory muscles are engaged; opisthotonos, if the body is drawn backwards by those of the back; emprosthotonos, if drawn forwards by those of the front of the neck and abdomen; and, if bent to one side, pleurosthotonos. 6. HYDROPHOBIA—spasms of the muscles of deglutition and respiration, from increased reflex excitability, and induced by the sight of fluids or efforts to drink them. 7. HEMIPLEGIA—loss of motion of one lateral half of the body, dependent on some pathological condition of the intra-cranial prolongation of the cord, or that above the decussation of the fibres of the pyramids. 8. PARAPLEGIA—paralysis of the muscles below a transverse line, dependent on lesions of the cord below the decussation of the fibres of the pyramids. The two latter lesions were sub-divided by *Todd* according as the muscles were in a rigid or relaxed state. 9. WASTING PALSY, the "paralysie musculaire atrophique" of *Cruveilhier*, in which organic change in the muscle substance is the primary lesion.

III. **Cerebro-spinal** diseases, or those affecting both the hemispheres and the cranio-spinal axis. 1. CATALEPSY. Unconsciousness, with a peculiar condition of the muscular system, so that when any part of the body is placed in any position ordinarily fatiguing, it remains rigidly fixed, and even the countenance retains whatever expression it may have had at the time of seizure. 2. EPILEPSY. Loss of consciousness, usually sudden, combined with convulsions—tonic at first, clonic afterwards, and followed by fatigue and sleep. The symptoms of the affection are, however, most various, and range in all degrees between the "petit mal" and "grand mal" of the French writers. 3. ECLAMPSIA. A form of epilepsy, acute, as it were, and usually due to poisoning, or developed in the parturient female, or in infants.

IV. **Neural** diseases, engaging the nerves only. 1. NEURALGIA. Pain along the course of a nerve, without any discoverable pathological condition, and usually periodic. 2. SUBJECTIVE SPECIAL SENSATIONS—as pruritus or formication, affecting those of the skin; perverted tastes, the gustatory nerve; increased or perverted sensitiveness to smells, in the olfactory nerve; tinnitus aurium, affecting the portio mollis; and ocular spectra, or flashes upon the optic nerve. 3. LOCAL SPASMS of special muscles, as cramp; or muscular viscera, as spastic disphagia, due to irritation of their motor filaments. 4. LOCAL PALSY, or loss of function in muscles supplied by some special nerve, as the facial, or in those of common sensation (anæsthesia), taste (ageustia), smell (anosmia), sight (amaurosis), or hearing (cophosis).

The last group of the abnormal conditions of innervation, as arranged by *Hughes Bennett*, is,

"V. **Neuro-Spinal** disorders, in which both the nerves and spinal cord are affected:

"DIASTALTIC OR REFLEX ACTIONS.—To this class belong all those diseases depending on irritation of the extremity of a sensitive nerve, acting, through the cord and motor nerves, on the muscular system, and producing a variety of spasmodic disorders, local or general, far too numerous to mention, which can only be understood by a thorough knowledge of the physiology of the diastaltic or excito-motory system of nerves."

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. Mention a few purely cerebral diseases.
2. Give the anatomical division of apoplexy, and *Abercrombie's*.

3. Sketch the pathology of tetanus.
4. How do hemiplegia and paraplegia differ as regards cause?
5. Give some examples of subjective special sensations.
6. What names are applied to the lost senses?

SENIOR.

1. What connexion can you show between abnormal states of nutrition in nervous centres and morbid phenomena, usually considered peculiar to them?
2. What are the principal varieties of insanity?
3. Enumerate all the causes of coma which you remember.
4. What diseases are attended with clonic spasm, and distinguish those which are reflex?
5. Is there any form of palsy inherent to muscles? Who first recognized it?
6. Contrast the phenomena of catalepsy, epilepsy, and eclampsia.

PARASITES,

VEGETAL and animal, infest the human body. Both have been classified according to their position; some plants living on the surface—epiphyta; others dwelling in mucous cavities—entophyta; and animal parasites can be similarly arranged as a epizoa and entozoa.

I. Vegetal. 1. Sarcina ventriculi—an alga discovered by *Goodsir* in vomited matters which usually are fermenting. Administration of the sulphites which evolve sulphurous acid efficiently checks their production. It has been found in the urine, fæces, fluid of cerebral ventricles, and in a pulmonary abscess. 2. Torula cerevisiæ—the yeast plant, which frequently forms on saccharine urine, and has been found on various parts of the alimentary passage, probably brought there by beer or other fermenting matters. In cholera patients it has been discovered in the vomit; but it does not seem to have any important connexion with that disease, as once supposed. 3. Leptothrix buccalis—a small yellowish mass which is found on the tongue, mixed with the fur or epithelium, unless it be morbidly clean. The foregoing are the most accredited algæ which have been found in man. Fungi are nearly as frequent. 1. Penicillium glaucum—which occurs in urine, vomited matters, and fæces. 2. Trichophyton tonsurans—which lodges in the hair bulb and shaft. The variety of pityriasis termed versicolor is said to depend on this plant by some; by others upon the microsporon. This disease is contagious, as also are the forms of tinea capitis, which depend upon the same fungus. 3. Achorion Schœnleinii—the plant which constitutes the disease known as porrigo favosa, or "true scald-head." *Bennett* proved its contagiousness by inoculation. Sycosis menti depends probably on the same parasitic plant. 4. Oidium albicans—the fungus found in thrush, aphthæ or muguet, and in diptheria. Other less known vegetal parasites are described in the great monograph of *Küchenmeister*, translated for the Sydenham Society by *Dr. Lankester;* and one plant has been found even infiltrated into the bones of the lower extremity, producing the disease known as "fungus foot," in India.

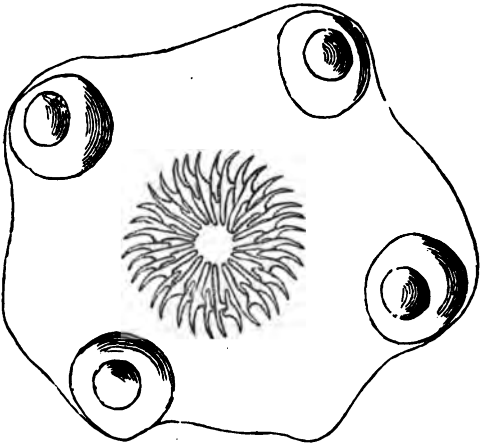
II. **Animal.** A. Epizoa. 1. The pediculus, or louse—an hemipterous insect inhabiting various parts of the surface of the body, such as scalp and pubis, or burrowing and multiplying enormously in subcutaneous cavities. So is constituted the disease, morbus pediculosus. Pediculi, taken from these different places, have slight zoological peculiarities. 2. Pulex, or flea—a dipterous insect of well-known habits. 3. Pulex penetrans, or chigoe—a troublesome parasite, chiefly found in South America. 4. The acarus scabiei, or itch mite—an animal which was demonstrated to be the cause of scabies by *Renucci*, a medical student. *Latreille* named the genus, sarcoptus. 5. Entozoon folliculorum—discovered by *Simon* in the sebaceous follicles of even healthy individuals, but produced in great numbers in persons with coarse greasy skin. It is represented on page 382.

B. Entozoa.—Of which the helmintha or intestinal worms are by far the most important for the physician to study. They may be classified in three groups: Nematoidea, Trematoda, and Cestoidea, which include in all 29 species—a number which may be gradually reduced, as some of them are probably but larval forms.

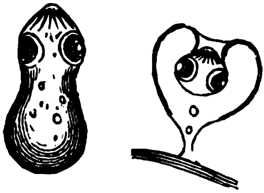
I. Nematoidea. 1. Ascaris lumbricoides, or common round worm, found in the small intestines, especially in children. 2. Ascaris alata, discovered by *Dr. Bellingham*, and the specimen is preserved in the Pathological Museum of St. Vincent's Hospital. *Küchenmeister*, without the slightest foundation, doubts that it is "a worm at all." It is so named from two membranous wings on the anterior extremity. It exists in almost every domestic cat. 3. Oxyurus vermicularis, or thread-worm, which lie in clusters in the rectum. 4. Trichocephalus dispar, a worm which was known to *Morgagni*. It is so common that in 29 persons who died in St. Vincent's Hospital of various diseases, *Dr. Bellingham* found it in 26, in one of whom 119 existed. Its habitat is the cœcum. 5. Trichina spiralis, an entozoon discovered by *Owen* in the voluntary muscles. It was believed to be the larva of the preceding species by *Küchenmeister;* but *Virchow*, by experiments on rabbits, has proved that it is a distinct animal. Its introduction into the human body in meat has produced death, with symptoms like those of typhus fever. 6. Anclystomum duodenalis, discovered in the gut from which it is named. 7. Strongylus renalis, which has been said to attain six feet in length. 8. Strongylus longevaginatus, distinguished by a sheathed penis, and hence so named, was found in the lung. 9. Spiroptera hominis, which was discharged from the bladder. 10. Filaria medinensis, or Guinea-worm, a formidable parasite which burrows in the subcutaneous and intermuscular areolar tissue. 11. Filaria oculi, found in the globe of the eye and lacrymal passages. 12. Filaria lentis, found by *Græfe* in a lens he had extracted. 13. Filaria lymphatica was found in the bronchial glands.

II. Trematoda. 14. Thecosoma sanguicola—or distoma hœmatobium, as *Bilharz*, its discoverer, named it—a worm found in the blood of the portal system. 15. Distoma hepaticum, or liver fluke, an animal about an inch long found in the biliary vessels. 16. Distoma lanceolaum, another species occupying the same situation. 17. Distoma ophthalmobium has been found between the lens and its capsule. 18. Distoma heterophyes in the intestines. 19. Distoma *Buskii*, which its discoverer found in the duodenum, some of them being 3 inches long. 20. Festucaria lentis, of which 8 were found in a lens the seat of senile cataract.

III. Cestoidea. 21. Tænia communis, the well-known tape-worm of this country. Its larva is known as cysticercus cellulosæ, the animal which infests swine especially, rendering their flesh "measly," and is capable of producing the tape-worm of man. The head of this latter parasite is represented in the accompanying woodcut. 22. Tænia nana. 23. Tænia flavopunctata. 24.



Head of Cysticercus.



Ecchinococci—one free; the other attached with head retracted, after Richardson.

Tænia echinococcus. The larva of this worm is usually called echinococcus, and the cavity in which it lives is usually known as an hydatid. 25. Tænia inermis. 26. Tænia acanthotrias. 27. Tænia tenuicollis; and 28. Tænia dentalis are rare, or even of doubtful existence. 29. Bothriocephalus latus, which is the common tape-worm in the North of Europe.

Infusorial animalcules also find a nidus in the human body. The following five species are described: 1. Paramecium, found in intestinal mucus. 2. Cercomonas, discovered in the stools in cholera and diarrhœa. 3. Trichomonas, found in vaginal mucus. 4. Virgulina, which occurs in the tartar around the teeth; and 5. Vibrio, the smallest of all human parasites; it has been chiefly observed in mucous discharges and those of cholera.

QUESTIONS FOR EXAMINATION.

JUNIOR.

1. How are human parasites primarily divided, and how subdivided according to their position?
2. Give examples of skin diseases due to plants.
3. Mention the chief examples of hematoid worms.
4. Which is the most frequent tape-worm? Describe its larva.

SENIOR.

1. What plant is most frequently cast from the stomach? Who discovered it?
2. Mention some examples of epizoa.
3. What variety of intestinal worm was discovered by *Dr. Bellingham?*
4. What parasites have been introduced in the human body by meat?

EXAMINATION PAPERS

ON

PHYSIOLOGY AND PATHOLOGY,

Recently issued by the principal examining bodies in Ireland and England, arranged in the order of this work, the number after each question referring to the page where the subject is discussed.

UNIVERSITY OF DUBLIN.

Degrees of M.B., Lic. Med., and M.C. Examinations.

EXAMINERS—*Professors, Harrison M'Dowel, Stokes, Law, R. W. Smith, and Apjohn.*

NATURAL HISTORY OF MAN.

Give the cranial vertebræ as distinguished by *Owen.* 25.

CHEMISTRY OF MAN.

In what situations, and under what circumstances, have "amyloid" substances been met with in human structures? 42, et postea.

The chemical composition of fatty matters, and their uses in the animal economy? 43.

What are the principal proteinic compounds of the animal body, and what the characters by which they are distinguished from each other? 45.

How is a solution of gelatine obtained, and what are the particulars in which it differs from one of albumen? Mention also the two vegetable acids, solutions of which are best distinguished by one of gelatine. 48.

DIGESTION.

Is the sanative action of stimulants in asthenic diseases to be attributed to their action as food alone? 53.

What proximate principles must enter into the composition of food, to fit it for the permanent nutrition and health of the higher animal? 55.

Is there any single substance which combines all the elements essential for nutrition, and which, therefore, may be regarded as a model alimentary substance? 58.

What experiments, and by whom instituted, prove that the food of the higher animal, in order to sustain life and health, must be varied? 57.

What remarkable local lesion occurred in the cases where the necessity for the variation of the food was established? 57.

Mention the different varieties of epithelium, and give examples of each. 64.

Describe the mucous membrane of the stomach in man? 77.

The composition of the pancreatic secretion, and its supposed uses in digestion. 86.

BLOOD.

What is *Müller's* proof of the dependence of the coagulation of the blood on the solidification of the fibrin previously in solution in the liquor sanguinis, and not on the aggregation of the corpuscles? 121.

CIRCULATION.

Describe and explain the phenomena of the pulse; and state its normal varieties, depending on age, sex, &c. 136.

How does posture affect the pulse? Is this influence equally operative in all conditions of the economy; and if not, what are the different states of the system by which it is modified? 136.

State the proofs of the existence of a "capillary force" as an agent in the circulation of the blood. 146.

Why did nature deviate from her ordinary course of lining canals with mucous membrane in the case of blood-vessels? 139.

RESPIRATION.

Describe the muscular apparatus of the trachea, and assign its probable functions. 151.

Describe the minute anatomy of the lung, and the arrangement of the pulmonary capillaries. 152.

Describe the functions of respiration and enumerate the principal agents in inspiration and in expiration. State the changes which are effected by this function upon the atmosphere and upon the blood. 154.

What is the composition of expired air, and how is its analysis made? Mention also the experiments which have induced physiologists to conclude that its carbonic acid is formed, not in the lungs, but in the course of the circulation. What is *Liebig's* theory of animal heat? 162.

SECRETION.

What secretions produce the greatest amount of mischief by their retention in the system? 177.

Give examples of excito secretory nervous actions. 179.

The structural anatomy of the lobules of the liver. 184.

Mention the origin, course, and function of the vena portæ. 180.

Mention the colour tests for bile, and those constituents of it on which the action of each depends. 189.

Give the general results of analysis of biliary concretions? 188.

In what part of the circulating system is sugar normally present; what is its source; and how is it got rid of? 192.

Illustrate the connexion that exists between the nervous influence and glucogenesis? 193.

What vessels in the kidney are analogous to the portal vein in the liver; and why? 201.

In what part of the kidney is the separation of the solid matters of the urine effected? 203.

State the sources of urea, the average diurnal amount excreted, and the circumstances which increase or diminish that quantity. 208.

Write the formula of lithic acid; mention its principal sources; the mode of separating it from the urine; and the characters by which lithic acid, lithate of ammonia, and lithate of soda, may be distinguished from each other. 210.

What are kreatine and kreatinine? 213.

What is the name and what the formula of the copulated acid discovered by *Liebig* in human urine? How may it be prepared from the urine of the cow, and what are the proximate principles into which it is resolved upon being boiled with muriatic acid? 212.

What is the name, and what the formula of the animal principle first detected in urine by *Petenkoffer*, and how did he procure it? 213.

What is *Garrod's* experiment for the diagnosis of gout? 211.

What conditions of the urine should lead to a suspicion of the disease of diabetes mellitus before testing for sugar? 219.

What is the most generally received opinion as to the pathology of diabetes mellitus? 221.

In testing for albumen by heat, or by the ferro-cyanide of potassium, a little acetic acid should first be added. Why is this the case? 224.

Name the urinary calculus which contains one-fourth its weight of sulphur; write its formula; and give the mode of effecting its analysis. 232.

THE DUCTLESS GLANDS.

Mr. Simon's theory of the functions of the thyroid gland? 243.

QUEEN'S UNIVERSITY.

M.D., Pass and Honour Examinations.

EXAMINERS—*Professors Carlile, Croker King, Corbett, M'Dowel, M'Donnell, Wharton, and Hughes.*

INTRODUCTION.

Explain briefly what you mean by vital force. 16.

Define the term cell, as used in physiological language, and state in general terms the varied offices which have been assigned to cells. 13.

What structures in the body are permanently cellular? 14.

NATURAL HISTORY OF MAN.

The excessive development of certain teeth and the action of certain muscles communicate a savage and ferocious expression to the human countenance; explain why such should be the case. 20.

What circumstances in the construction of the human skeleton prove that the erect position is natural to man? 17.

Enumerate the cranial vertebræ, according to *Owen.* 25.

Mention what constitute their hœmal arches. 27.

What is animal dextrine? Where is it principally met with, and what are its chief characteristics? 42, et postea.

CHEMISTRY OF MAN.

Give an account of adipose tissue and of fat. State the composition and the sources of fatty matter. Mention the amount of fatty matter normally present in the blood? 43, et postea.

What is cholesterine? Where is it formed, and in what excretion is it most abundant? 44.

To what circumstance does the solubility of albumen appear to be due? 46.

In order to retain fibrin in a state of solution what conditions are necessary? 47.

What do you understand by the term casein? whence is it obtained, and in what respect does it differ from albumen? 47.

DIGESTION.

For what different purposes is aliment required by man? 51.

In what essential particular do plants and animals differ in the nature of their food? 51.

Classify alimentary substances into groups, and afford an outline of their composition, also of their relative degrees of digestibility and nutribility? 52.

Has the supply of food a marked influence upon the size of the individual? In which of the two kingdoms, animal or vegetable, is the result most manifest? What animal tissue is directly increased by an over supply of food? State the circumstances which favour this deposition or growth. 53, et postea, and "Lectures on Public Health."

What are the most favourable conditions for fattening animals? 176.

Enumerate the several nutritive principles necessary in food which is capable of sustaining the entire system. 57, and "Lectures on Public Health."

To what extent is gelatine of use as an article of food? 56.

What appears to be the most satisfactory explanation which has been afforded as to the cause of the sensation of hunger? 61.

Cases have been recorded of human beings having lived for years without food; prove on physiological principles that life could not have continued under such circumstances? 62.

How do you know that the sensation of hunger is not produced by mere emptiness of the organ, or by the action of the gastric fluid upon its coats? 61.

Suppose a human being to die of starvation, which tissue loses most weight, which least? 62.

From what facts does it appear that the sensation of thirst frequently depends upon a deficiency of fluid in the body? 63.

What is the general structure of mucous membrane, and what purposes does its epithelium serve? 64.

Describe the appearance of ciliated epithelium, and explain what you conceive to be the nature and cause of ciliary motion. 65 and 296.

What varieties of epithelium are met with on the mucous membrane of the intestinal canal? 65, 77, 87.

Mention the different classes of teeth. State the appearance presented on making a vertical section. Describe the anatomical elements of the teeth and their microscopic features. 66.

The typical dental formula. 66.

What appearances are presented by vertical and transverse sections of enamel placed in the field of a microscope? Describe its mode of developement, and state what structure of the lower animals it resembles. 68.

Describe the development of a tooth. How many deciduous teeth are there? 69.

The microscopic characters and composition of a tooth. 67.

Describe the processes of mastication and deglutition. 70, 73.

Describe the composition of the salivary secretion, and its use in alimentation. 72.

How is the glottis protected during deglutition? 75.

In what part of the alimentary canal is sugar generated from starch? What interferes with this development in the stomach? 73.

State the microscopic characters of the gastric glands or follicles. 77.

Describe the structural anatomy of the stomach. 77.

Give a short summary of the nature of stomach digestion. 79.

Detail the researches and experiments of *Dr. Beaumont* on the subject of digestion. 79.

How can pepsine be obtained? and what is its supposed action in the digestive process? 80.

What is the chief agent in chymification? Who first detected it? How would you prepare an artificial digesting fluid? 80.

What is albuminose? 80.

If white of eggs be swallowed raw what changes does it undergo in the stomach? 80.

If brown bread be eaten mention what takes place in the digestion of its various ingredients? 59, 84.

Is an organic compound, which contains elements necessary for nutrition, of necessity nutritive? 59.

How has the action of the gastric fluid on solid food been studied by different observers? 78.

What are the changes which food undergoes in the stomach? 81.

Mention the experiments of *Magendie* in reference to the cause of vomiting. 83.

Can you define the extent of the alimentary canal which is engaged in calorifacient digestion? 84.

Describe the minute structure of the pancreas. 85.

State some recent researches as to the use of the pancreatic secretion. 86.

Mons. C. Bernard instituted a series of experiments with the view of ascertaining the use of the secretion of the liver, in the process of digestion, as distinguished from that of the pancreas. What animal did he select, and why did he choose this particular animal?

A patient is emaciated, and, amongst other symptoms, has adipose diarrhœa. As a physiologist, what opinion would you give as to the probable nature of his ailment? 86.

Give an outline of the function of chylification, and describe the structural anatomy of the small intestines. 87.

From what source is the alimentary mucus supplied? 87.

What is the relative position of the basement membrane with respect to the other structures forming an intestinal villus? 88.

Contrast the mucous membrane in the upper and lower portions of the duodenum. 88.

Give an account of the changes which the alimentary mass undergoes from its passage through the pyloric valve, until its arrival at the ilio-cœcal aperture 89.

Enumerate the glandular secretions which are poured out upon the gastro-intestinal mucous membrane, and describe more particularly the proper intestinal glands. 89, 99.

ABSORPTION.

Through what channel, and in obedience to what physical law, are matters in a state of perfect solution, and water, said to be introduced into the system? 94.

Mention the experiments of *Magendie*, in order to prove venous imbibition or absorption.

Does absorption take place from the stomach in vertebrata? if so, state its nature and how the fact has been proved. 96.

To whom do you attribute the discovery of the lacteals? Give an account of the structure and office of this division of the absorbent system. 99.

Explain the modern theory of lacteal absorption, and point out the differences between the theories of *Goodsir* and *Kölliker*. 99.

What are the conditions which either promote or retard the entrance of poisonous substances into the sanguiferous system? 96.

To what circumstances is the milky colour of the contents of the lacteals due? 101.

Give a general description of the lymphatic system. 101.

Mention the more remarkable opinions which have been held as to the functions of the lymphatic vessels. 104.

BLOOD.

Are you aware of any facts which prove the impropriety of performing an operation likely to be attended with much loss of blood on an animal while fasting? 106.

Describe the red corpuscles in man, fishes, and reptiles. 107.

Certain red corpuscles of the blood present the following characters:—

(*a.*) Of large size, elliptical nucleated,
(*b.*) Nearly circular nucleated.
(*c.*) Circular and non-nucleated.
(*d.*) Elliptical and non-nucleated.
(*e.*) Circular non-nucleated, very small, one-third the diameter of the human corpuscles.

Can you say to what animal or class of animals each variety probably belongs? 108.

Prove their cell nature, and explain their functions. 109.

The change of colour in the blood during respiration has been ascribed to a change in the state of the iron in the hæmatine produced by the contact of gases with the blood; how has this opinion been refuted, and to what other cause has this change in colour been attributed? 110.

The peculiar colour of the hæmatine in the red corpuscles of the blood has been supposed to depend on the iron it contains; has this been denied; if so, by whom, and on what grounds? 110.

How has it been proved that the alterations in the colour of the blood caused by submitting it alternately to the influence of oxygen and carbonic acid gases, are more due to change of form than of composition? 110.

Contrast the red and white globules of the blood. 112.

What effect has starvation upon the quantity of fibrin contained in the blood? 115.

How are the elements of the blood combined?

(*a*.) In circulating blood.

(*b*.) In coagulated blood. 118.

Is there any exception to the general law which establishes a relation between the number of red corpuscles in the blood, and the activity of the respiratory process?

Under what conditions of health is the blood in certain veins of a scarlet colour? 118.

Describe the changes which take place during the coagulation of the blood, and the circumstances which accelerate or retard the process; and also the causes said to produce the condition called buffy coat. 119.

What prevents the coagulation of circulating blood? 121.

Is there any peculiarity in the blood drawn by a leech which partially accounts for the difficulty in arresting the bleeding from a leech bite? 120.

Mention some reasons in support of *Mr. Hunter's* opinion, that "the coagulation of the blood is an operation of life," or a process of organization. 120.

Do the globules present any peculiar appearance in inflammatory blood, or do they appear to have any influence in forming the buffy coat? 122.

Explain the appearance of inflammatory blood, and the cause of the "buffy coat." 122, et postea.

In the operation of transfusion of blood, is it of any consequence whether the animal from which the blood is drawn be fasting or in a state of repletion? 123.

CIRCULATION.

What objects are fulfilled by the function of circulation? 124.

State, briefly, the principal facts connected with the discovery of the circulation of the blood; the discoverer; the facts which led to the discovery; the proofs on which it rested; and the additions to those early discoveries made at subsequent periods. 125.

How do you prove the circulation of the blood? 125.

Describe the general arrangement of the muscular fibres of the heart, and their microscopic characters. 126.

Give a description of the valves of the heart, and explain their functions. 127.

Explain the "safety valve" function of the tricuspid valve. 128.

Describe the sensible phenomena which attend the action of the heart. 130.

Describe the structure and office of the aortic valves. 128.

Describe the sounds of the heart, their rhythm, and their supposed origin. 130.

What do physiologists generally consider to be the causes which produce the first sound of the heart? 131.

Is the heart the sole agent in carrying on the circulation of the blood? 135.

How would you refute the doctrine that the heart is the sole cause of the circulation of the blood? 135.

Give an explanation of the arterial pulse; mention some observations made with a view to determine its cause; describe the varieties in its condition under different circumstances. 136.

How long does a pulse wave usually take to travel from the heart to the extreme arteries? Suppose the interval was increased or on the contrary was diminished, what inference would you draw in each case as to the state of the individual's health? 136.

Could you form any opinion as to the state of an individual's health by a comparison of the pulse at the wrist with the impulse of the heart in the cardiac region?

What may be considered the rate of the pulse in health at the following ages?—

Before 1 year old.
At 10 years „
At 20 years „ 137.

What is the normal ratio which the rate of the pulse bears to that of respiration? 157.

Give a physiological explanation of the terms hardness, fulness, compressibility, and incompressibility, as applied in medical language to the pulse. 137, et postea.

Are you aware of any arrangements of the arterial tubes about the larger joints, in order to secure a constant supply of blood to the limb below? 141.

Give some familiar instances of the influence of the nervous system on capillary circulation. 147, et postea.

Describe the structure of the veins. Mention the general plan on which the venous system is constructed; state the forces which promote the circulation of blood through the veins. 148.

What forms of venous pulse have been observed? Explain their production. 148.

Does the injection of certain substances into the veins of animals, afford any evidence with respect to the rapidity of the circulation? 136.

RESPIRATION.

What is the use of the trachealis muscle? 152.

Mons. C. Bernard caused rabbits to respire an atmosphere charged with minute particles of carbon; the latter did not penetrate into the air passages. What prevented their entrance? 152.

Describe the anatomy of a pulmonic lobule, particularly noticing the arrangement of the air-cells and vessels, and assigning to each of the latter its peculiar office. 152.

Can you trace any functional analogy between the vessels of the lungs and those of the liver?

Describe the functions of the intercostal muscles. 154.

Describe the mechanism of respiration. Mention the muscles and nerves which are engaged in that function. 154.

Mention the nerves which are concerned in the function of respiration. 158.

Through the reflex action of what nerves can the respiratory muscles be called into action? 158.

What explanation would you afford as to the cause of the first inspiration at birth. 158.

Mention what may be considered in the adult to be—1, the average number of inspirations per minute; 2, the average amount of air taken in at each inspiration; 3, the maximum amount of a forced expiration; 4, the average vital capacity of the lungs. 159.

What amount of air remains in the adult male lungs after the most powerful expiration? 159.

Give an account of some observations and experiments which have been conducted with a view to ascertain the capacity of the chest for respiration. 159.

Independent of the absolute capacity of the chest, the amount of air which can be expelled from the lungs by the deepest expiration after the fullest inspiration bears a singular relation to the height of the individual, as was discovered by *Mr. Hutchinson.* Can you state the law which regulates the quantity? 160.

What is the composition of atmospheric air, and what changes does it undergo during respiration? 162.

What part does oxygen play in vital action? 162.

What are the changes in the state of the atmospheric air produced by animal respiration? 162.

Has sex any influence on the amount of carbon exhaled from the lungs; if so, at what periods or under what conditions of life is the difference most marked? 163.

What are the alterations in the state of the blood, dependent on the due performance of respiration? 163.

Are you aware of any experiments having been made on warm-blooded animals, the object of which was to show that the amount of carbonic acid expired is influenced by the external temperature? If so, relate them, and state the results which have been obtained. 163.

What changes are effected in the blood by respiration? 163.

Describe the nature of the respiratory process, according to the views of *Lagrange.* 163.

What do you understand by the term asphyxia? Enumerate the principal modes by which that state may be induced. What are the physiological conditions of the organs of circulation and respiration during asphyxia? 165.

In what manner does the suspension of the respiratory process in mammalia arrest the general circulation? 166.

Why is the blood in cases of asphyxia found accumulated in the right cavities of the heart, and in the venous system? 166.

Suppose a warm-blooded animal to be confined in a limited quantity of atmospheric air; what means, if adopted, would prolong its life for the longest period?

A small animal (a sparrow, for example), is left in a bell glass, to breathe the same air over and over again, and lives *three* hours; at the end of the *second* hour a healthy vigorous sparrow is introduced, and it expires immediately. Can you offer any explanation of this result?

An individual exposed to the fumes of burning coal is asphyxiated, blood drawn from a vein is of a bright scarlet colour; what deleterious gas has caused the suffocation? 166.

The classification of vertebrate animals based on their temperature. What class of evertebrate animals have the power of evolving much heat? 168.

What are the physiological conditions of an animal during hybernation? 170.

Explain why a person descending in a diving-bell does not suffer from muscular inactivity, or experience a sensation of cold, though surrounded by the chilling influence of the water. 171.

The modern theory of animal heat; mention *Crawford's* theory? 173.

In what class of animals is the skin most efficient as an organ of respiration? Illustrate this. 172.

Suppose you had an animal for operation (a rabbit, for example), and that you wished, by vivisection, to produce increase vascularity of the conjunctiva, contraction of the corresponding pupil, and increased heat of the ear, how would you proceed? Can you offer any explanation as to why these remarkable phenomena should result from the section you had made? 173.

Give an account of the influences which regulate the temperature of the human body? 174.

Does clothing impart heat? "Lectures on Public Health."

By what means is man enabled to preserve, under certain limitations, an uniform temperature, though exposed to excessive heat or cold? 174.

SECRETION.

What facts support the theory, that the various secretions exist in the blood, and are not fabricated in the several glands? 177.

In what way would the secretion of a salivary gland be effected by galvanic stimulation of its sympathetic nervous supply? 179.

Suppose you wished, by means of galvanism, to promote secretion from the parotid or submaxillary gland, what nerve in each case would you excite? 179.

Describe the corpuscles that have been detected in the fluid to which the term colostrum has been applied; and state under what circumstances this fluid is found, and its supposed use. 180.

Are you aware of any remarkable difference in the product of the decomposition of milk at a temperature of from 50 to 75 degrees Fahrenheit, as compared with its decomposition at or above 90 degrees Fahrenheit? 182.

Which of the constituents of milk is materially affected by the quality of the food consumed by the animal? 181.

Describe the structural anatomy of the lobules of the liver. 184.

Mention how you would inject the liver so as to exhibit the arrangement of its capillary vessels. Mention the appearances of these vessels under the microscope. 184.

Describe the function of the liver: give an account of the composition and use of the bile. 187.

What fact has been adduced to prove that the secretion of bile takes place, though not required for the purpose of digestion? 187.

Describe the peculiarities of the blood of the vena portæ. 192.

Is the biliary secretion solely excrementitious, or has it a purpose to serve in connexion with the digestive function? Support your views by appealing to comparative anatomy, and by stating the results which have been obtained by experiment. 189.

What other duties, besides the secretion of bile, does the liver perform? 189.

What structure would immediately suffer if the glycogenous matter were deficient in the animal system? 193.

Artificial diabetes has been produced by a mechanical injury of a certain part of the medulla oblongata. Have any explanations of this curious result been offered? 193.

Describe the kidneys during fœtal existence, and state whether there is any analogous condition as a permanent arrangement in some animals.

Describe the arrangement of the minute vessels in the kidney, and their relation to the tubuli uriniferi. 197.

Describe the manner in which the elements of the urine are separated from the blood. What is the average specific gravity of healthy urine? Is the specific gravity of this secretion affected by external influences? 205.

What is the average quantity of urine passed in twenty-four hours by a healthy man, and what should be its normal specific gravity? 205.

What are the solids excreted by the kidney; how are they separated; and what provision is made for their effectual removal? 206.

State the average amount of urea and of uric acid which is excreted by an adult. Compare the results of the investigations of former physiologists with those of recent date. 207.

Give the chemical composition of these substances. 207.

How would you determine the quantity of urea in any given specimen of urine? 208.

By the waste of what structures are the relative proportions of the urinary elements affected? With what compound is urea isomeric? 208.

Explain the train of symptoms which would result from the extirpation of both kidneys—in a dog, for example. 209.

Are you aware of any remarkable change which is effected in the saline ingredients of the urine by the presence of inflammatory action, accompanied by copious exhalations? 211.

Urine passed by a patient is at first perfectly transparent, but, on cooling, becomes opaque, and ultimately deposits an amorphous sediment of a yellowish or pinkish colour. What is, probably, the chemical nature of the deposit? 211.

Two specimens of urine, which are transparent, becomes opaque on being boiled; the addition of nitric acid restores the transparency of one, but has no effect of the kind on the other. What conclusions would you draw as to the cause of the opacity which occurred in both instances on the application of heat? 216.

Two specimens of urine examined: one of s. g. 1,040, the other s. g. 1,010. The former, on the addition of a weak solution of sulphate of copper, and of liquor potassæ, becomes of a yellow ochre colour on being heated; the latter opaque on the application of heat. What is the nature of the ingredient in each specimen of urine which causes these changes? 223.

What is the best description of vegetable food for a diabetic patient—and why? 221.

DUCTLESS GLANDS.

Describe the structural anatomy of the spleen. 237.

Describe the splenic Malpighian corpuscles. Under what circumstances are they found best developed? 238.

What reasons have been given for regarding the spleen as an appendix to the absorbent system? 239.

Describe the suprarenal capsules. 240.

Describe the thyroid body. 242.

Mention in their order the processes which are included under the function of nutrition. 245.

INNERVATION.

Describe the microscopical features of the different forms of nervous tissue, and assign to each form its proper function. 248.

Describe the microscopical structure of a nerve fibre? 249.

Do nerve fibres anastomose? 250.

Give examples of the histological action of certain substances upon sensitive and motor nerves, muscular tissue, and blood discs. 250.

Is there any connexion between the susceptibility of an animal to disease and the development of its nervous system?

What arguments oppose the theory, that centrifugal nerves act merely as conductors of an influence which has originated in a nerve centre? 252.

What do you conceive to be the true relation existing between electricity and nervous force? Give the grounds for your opinion. 253.

How can it be proved by experiment that there is a property in a nervous ganglion which enables it to hold in reserve a portion of the influence brought into it, so as to keep up the action for a period of time after the original disturbing causes have ceased? 254.

What are the uses of the liquor Cotunnii? Mention its composition and the causes which influence its amount. 259.

Mention any peculiarities which have been insisted on by some physiologists, as existing in the circulation within the cranium. 260.

What are the peculiarities of the circulation within the cranium, chest, and abdomen? 260, et antea.

State whether the circulation of the blood within the cranium is influenced in any respect by the process of respiration. 261.

Have you, in the adult human subject, any remnant of the serous canal, which in the fœtus, prior to the sixth month, extended through the entire cord? 266.

How do you show that the spinal cord is endowed with powers independent of those resulting from its connexion with the brain. 267.

Explain the nature of the reflex function performed by the spinal cord and its nerves. 267.

How can you prove that sensation is not a necessary link in the chain of reflex actions? 268.

What are the effects which follow a division of a lateral half of the spinal cord in the back? 269.

What effects on sensation and voluntary motion would result from the following lesions:

(*a*). Disease in any part of one half of the brain, except in the medulla oblongata at the decussation of the pyramids.

(*b*). Disease implicating a lateral half of the medulla oblongata, at the decussation of the pyramids.

(*c*). Disease implicating one lateral half of the spinal cord. 269.

In the French translation of *Sir Charles Bell's* "Nervous System of the Human Body," a case is recorded of a man who, from a fall, had entirely lost his sensibility on the *right* side, though preserving his power of movement; and had entirely lost the power of movement on the *left* side, though preserving his sensibility; where was the injury to the nervous centre? 270.

Describe a spinal nerve. By what physiologists were the functions of the spinal nerves first accurately determined? 271.

Describe the medulla oblongata; define its limits, and trace its segments. 274.

Enumerate the commissural fibres of the brain from above downwards. 283.

Does there appear to be any relation between the symmetry of the convolutions of the brain and the general development of the organ? 283.

Of what peculiar arrangement of the nervous system in invertebra does the fourth ventricle appear to be the remnant?

Mention the pathological conditions and anatomical lesions which can be produced by the excitation of the solar plexus of nerves and its efferent branches. 289.

Suppose one hand be plunged into a freezing mixture, in what manner would the immersion affect the other hand? Explain the phenomenon. 292.

MOTION.

If white fibrous tissue and yellow elastic tissue co-exist in the same structure, how can you, with the microscope, distinguish the one from the other? 298.

What structures in the body are, for the most part, composed of white fibrous tissue? 298.

Contrast the physical properties and microscopical features of the white, with those of the yellow, fibrous tissue, and state to what uses these two structures have been applied in animal construction. 298.

Describe the appearance of adipose cells, as seen in the field of a microscope; and also state if any provision exists to prevent the transudation of their oily contents. 300.

State the various uses to which fat is applied in the economy of man. 301.

Describe the microscopic appearance of articular cartilage. 301.

What forms of fibro-cartilage are met with in man? 301.

The uses and histological characters of these structures? 301.

Describe serous and synovial membranes. To what cause do you refer the difference which is observed in the results of inflammation occurring in these textures? 303.

Give a classification of the joints, with examples of each form. 305.

Give the qualitative analysis of the chemical composition of bone. 306.

Give a description of the minute structure of bone, and explain its mode of nutrition. 308.

How is bone primordially devoloped? 311.

Describe an involuntary muscular fibre, and state in what situations such is found, and what functions it ministers to. 312.

Describe the appearances presented by a voluntary muscular fibre (as seen in the field of a microscope) in a state of repose, and during its contraction. 313.

Describe the microscopic structure of voluntary muscle. 313.

How has it been proved that muscular contraction is accompanied by the production of heat and sound? 317.

Have muscular fibrillæ a variable size in different animals? 314.

How has it been proved that the principle to which the characteristic flavour of different meats is due does not reside in the sarcous element? 314.

How and with what results have the vital properties of muscular fibres been investigated experimentally by physiologists? 317.

What are the peculiar physiological characteristics of muscle? 316.

Contractility of muscle is by some considered a "vis insita;" by others, a "vis nervosa." Which of these opinions is most generally approved of at the present time? and state the reasons why it is so. 316.

Give examples of tonic muscular contraction in health and in disease. 316.

What is peculiar about the action of the sphincter muscles; and on what does this peculiarity seem to depend? 317.

In what manner would the nutrition of a muscle and of a bone be affected by depriving either of these structures of its nervous supply?

Define, and discriminate between, the vis mortua, the vis insita, and the vis nervea. 319.

Contrast the behaviour of striated with that of non-striated muscular fibres under the influence of direct stimuli. 318.

Are you aware of any relation which exists between the duration of muscular contractility after nutrition had ceased, and the activity of the respiratory process during life? 319.

Rigor mortis supervenes unusually early in a human corpse, and is of short duration; mention the several circumstances which may have produced these results. 319.

In which of the voluntary muscles does the cadaveric stiffening first appear? 319.

What are the fundamental laws regulating the electrical conditions of muscle in recently dead animals? 319.

Describe the peculiarities of attitude presented by a stiffened human corpse, death having occurred in the supine posture. 319.

What form of lever is chiefly employed in the animal economy? Give examples in the body of each form. For what reason is one form so much more generally employed in animal structures? 320.

Can you explain how a force acting on the ilio femoral articulation, in a direction upwards and forwards (as in walking), can maintain horizontal progression? 321.

A section of a bone is observed to have large lacunæ; could you draw any general conclusions from the examination of this specimen as to the other corpuscular elements of the animal from which the specimen has been obtained? 308.

Why is it possible for a drunken man to run without falling, though he cannot walk or stand? 322.

In the action of striking a blow, to what order of lever do the bones of the forearm belong? Explain why? 321.

Whereabouts is the centre of gravity situated in a man while standing with his arms against his sides?

VOICE.

According to *Willis*, what relative position of the vocal cords is necessary for the production of voice; by the action of what muscles can this adjustment be effected? 324.

SPECIAL SENSES.

Describe the structure of the skin. 332.

Describe the structure of the human skin; also the arrangement of the sudoriferous glands, and sebaceous follicles, and the nature of their secretions. 332.

Describe the glandular structures of the skin. 337.

Do you know of any experiments having been performed in order, if possible, to determine the relative sensibility of various parts of the human body? If so, state the results obtained. 338.

Why does the cavity of a tooth felt by the tip of the tongue appear larger than it really is?

Two fingers having been crossed, and then moved over a spherical surface placed between them, the latter appears to be double; explain this. 339.

What external circumstances influence the amount of the cutaneous exhalation? 341.

In what situations has the sense of taste been found to reside, and what nerves supply these parts? 342.

Determine the limits of the true olfactory region. 349.

Describe the cerebral connexions of the olfactory nerves. 349.

Describe the mode of termination of the filaments of the olfactory nerve. 350.

Offer proofs to show that the sense of smell resides in the olfactory nerves and lobes. 351.

What nerves are distributed to the nasal cavity and its orifices? Can you assign any reason why the nose should receive its nervous supply from such varied sources. 351.

Describe the oblique muscles of the eye. Mention the different opinions which have been held as to their influence on the motions of the eyeball. 354.

Describe the lachrymal gland, the tarsal cartilages, and Meibomian follicles. 354.

What method of removing the eyeball has been based on a correct knowledge of its connexions? Enumerate the parts divided in this operation. 356.

Give a description of the cornea; explain how its nutrition is effected. 360.

Describe the transparent media of the eye, and state the provisions in that organ for correcting or counteracting spherical and chromatic aberrations. 360.

Describe the structure and office of the choroid coat of the eye. 361.

Describe the choroid epithelium, its situation, appearance, and the mode of preparing it for examination. 363.

Distinguish and describe the pigmentum nigrum and the membrana pigmenti. 364.

Describe the form, situation, and uses of the ciliary muscle, by whom was it first described, and in what class of animals. 364.

Are you aware of any means by which an individual could distinguish between a real object and a mental illusion?

Describe the structure and action of the iris. 364.

The nervous supply of the iris: state the functions of its different nerves. 366.

Give a description of the retina. 368.

What do you understand by the term cerebral or inverse vision? Give an example.

What is the structure of the hyaloid membrane? 368.

Who first described the foramen centrale of the retina? In what animals has it been since observed? 370.

Describe what you conceive to be the mechanism by which the human eye is adapted to distinct vision at different distances, and mention any experiments you know on this subject. 375.

On bringing an object close to the eye the pupil is observed to contract. Is this diminution of the pupil's diameter of any optical value? 375.

What offices does *Professor Draper* assign to the following layers of the retina:—

a. The vesicular.
b. The granular.
c. Membrana Jacobi, or rods. 377.

What arguments have been advanced in support of the theory that the choroid coat of the eye is the real optical screen, and that the retina is only secondarily affected? 378.

What is the situation of the insensible spot of the retina? How could you prove its existence? 378.

What relation in colour exists between luminous images and the resulting ocular spectra? 378.

Distinguish the essential and accessory parts of the organ of hearing; mention the order of addition of the accessory parts in the animal series. 381.

Describe the cavity of the tympanum and the parts contained in it. 381.

Describe the muscles of the internal ear. 384.

State the physiological uses which have been assigned to the following portions of the organ of hearing:—the vestibule, the semicircular canals, the cochlea, the tympanum, the ossicula, and the external ear. 389.

How is the external auditory canal developed?

What are the uses of the Eustachian tube? 386.

Describe the cochlearis muscle. 387.

What special use has been assigned by *Professor Draper* to the spiral lamina of the cochlea?

Trace an analogy between the eye-ball and its appendages, and the organ of hearing and its appendages. 390.

Trace the portio dura nerve from its origin to its final distribution. What ganglion has been described in connexion with it? What branches of communication does that ganglion give off or receive? What effects have been observed as the result of injury or disease involving the trunk of that nerve? 393.

In some cases of paralysis of the portio dura the four senses—sight, smell, hearing, and taste, are more or less impaired, also the process of deglutition; state the several anatomical communications of this nerve which may, in some measure, explain these effects. In such cases, is the uvula ever affected, and how? 394.

Determine the distribution of the motor and sensory portions of the pneumo-gastric nerve. Mention the branches which are (*a*) purely motor, and those which are (*b*) senso-motory, distinguishing those in which the motor and those in which the sensory filaments predominate. 395.

Describe the inferior laryngeal nerves. Mention some experiments made on animals in order to determine their function. 395.

The action of which muscles of the face appear to be peculiarly identified with human expression? 394.

REPRODUCTION.

Explain the nature and the development of the so-called spermatozoa. 402.

Describe the umbilical vein and hypogastric arteries of the fœtus. 412.

Describe the changes which take place in the vascular system of man at birth. 414.

Can you explain why those changes take place? 414.

Mention the peculiarities of the fœtal heart. 414.

What are the vascular arrangements peculiar to the fœtal liver? 414.

How is the depuration of the blood effected in the fœtus? 414.

Describe the ductus arteriosus and its office. 414.

The duration of vital activity is in the inverse ratio of its energy.—Examples.

Contrast somatic with molecular death. 416.

Describe the effect of cold [illegible] on the several tissues and secretions. 416.

PRINCIPLES OF DISEASE.

In what diseased states of the system are the following changes effected in the blood: Fibrine increased or diminished in quantity, red corpuscles increased or diminished in number, albumen diminished in quantity. 419.

What elementary tissues in the human body are capable of regeneration when destroyed? 438.

State the effects frequently produced on man by a too abundant supply of food? 419.

What circumstances are said to favour fatty degeneration? 452.

How are tumours classified, and in what respect is cancer unlike other tumours? In what situations are fibrous tumours most frequently found? Certain tumours are more often pulsatile than others; which are they? How is a fatty tumour diagnosed? What are its situations, and the ages at which it occurs? What are the rules to be adopted with regard to the treatment of tumours in general? 459.

What do you understand by a chronic mammary tumour? How does *Velpeau* differ from *Sir Astley Cooper* upon the question of the origin of such tumours? What is the derivation of the term adenoid, applied to them by *Velpeau*? How are these tumours to be recognised? 465.

Give a brief definition of the following words, or make use of a phrase showing that you understand the meaning:—stroma, plasma, parenchyma, cytoblast, blastema, cell-nucleus. Glossarial Index.

LONDON UNIVERSITY.

M.B., B.A., & B. Sc. Pass and Honour Examinations.

EXAMINERS.—*Professors Kiernan, Sharpey, Carpenter, Busk, Huxley, Redfern, Jenner, Savory, Parkes, Tweedie, Taylor.*

INTRODUCTION.

What portions of the fully-formed human organism are composed of simple cells; and to what functions are they respectively subservient? 13.

NATURAL HISTORY OF MAN.

What are the anatomical peculiarities of the human frame which especially fit man for his erect posture? 17.

What are the chief points of structural difference between man and the higher quadrumana? 20.

Compare and contrast the human brain and skull with those of the higher apes. 20.

Explain the principle of homology, as manifested in the construction of the vertebrate skeleton, and give examples in illustration. 24.

Describe the elements of a typical vertebra according to *Prof. Owen*; show how these are arranged in a dorsal vertebra of man; and enumerate the constituent parts of the neural arches of the cranial vertebræ, according to the ordinary anatomical nomenclature. 25.

CHEMISTRY OF MAN.

What is the source of fat, and what are its uses in the human economy? 43 et postea.

Enumerate and classify the proximate principles found in animal bodies, and point out the chemical peculiarities by which they are distinguished from other organic compounds. 45.

State the chemical composition and relations of albumen and fibrin? 46.

What organic compounds predominate in muscle, connective tissue, bone, cartilage, and nervous tissue respectively? 47 et postea.

DIGESTION.

What are the sources of the demand in aliment for the human body; and what are the principal conditions by which that demand is regulated? 51.

Draw a comparison between the chemical physiology of vegetables and that of animals. 51.

Mention the chief alimentary principles of human food; state the purposes which they severally fulfil in the process of nutrition, and describe the changes which they undergo in digestion, pointing out the agencies by which those changes are effected. 52.

Classify the proximate constituents of a piece of bread under the two heads of "nutritious" and "non-nutritious." Suppose the piece of bread to be eaten, and trace out the changes which it undergoes in its passage from one end of the nutritious canal to the other. 58.

Enumerate the principal classes of alimentary materials; state the purposes to which they are severally subservient in the economy; mention the chief proximate components of bread, meat, potatoes, milk, rice, and arrow root; and state the quantity of food ordinarily requisite to maintain the human system in vigorous action. 59.

Describe and explain the effects which ensue on totally depriving an animal of food. What differences are observed among animals, as to their power of enduring abstinence from food, and how are such differences accounted for? 61.

Describe the principal stages of the digestive process, in its relation to each of the most important proximate principles of human food; distinguishing the share taken by each of the principal secretions concerned in it. 63.

Give an account of the structure and properties of mucous membrane in general; and describe that of the stomach, and of the small and large intestines in particular: the description to include an account of the ultimate arrangement of the blood-vessels, the epithelium, the follicles of *Lieberkühn* and the glands of *Brunner* and *Peyer*. 64.

Describe the external configuration and the position of the teeth of the adult and their internal structure, so far as it can be discerned with the naked eye. 65.

Give a general account of the history of the development of the human teeth, both of the temporary and permanent series; point out the analogies between its successive stages and the modes of dentition of the lower vertebrata; and describe the organic structure and chemical composition of the dentine, enamel, andcementum. 69.

What are the nerves concerned in the act of deglutition; and what are the inferences you might draw from the circumstances under which that act may be performed (as shown in states of disease, and by experimental inquiries), with regard to the nature of reflex action in general? 76.

Describe the structure of all the glands which are connected with the alimentary canal of man, except the salivary, hepatic, and pancreatic; and give an account of the known or supposed functions of each? 88.

What influence do the nerves exert over the digestive functions of the stomach, and in what respects does artificial digestion differ in its results from that effected in the living animal? 80.

State the composition of the gastric juice and explain the theory of its action? 79.

Describe the process of digestion and of the absorption of its products, in the case of—1, wheaten bread; 2, meat; 3, milk. 81.

Describe the duodenum, more particularly with reference to the minute structure and functions of its different coats; the nature of the secretions which are poured into the intestinal canal at this part, and their influence on the process of digestion? 84.

Describe the minute structure of any part of the small intestine of man from the free mucous to the free serous surface; and give an account of the functions of the component organs of the part. 87.

Describe the structure and arrangement of the mucous membrane of the intestines, pointing out the characters it presents in different parts of the canal. 87.

Suppose a healthy man to be dieted on bread, fat meat, and water, of what substances would his fæces consist, and whence would they be derived? 92.

ABSORPTION.

Explain the process of absorption in animal bodies, noticing the principal theories that have been entertained respecting it; mention the circumstances or conditions by which its rapidity is influenced and enter fully into the explanation of the phenomena of osmosis. 94.

Describe the endosmotic or exosmotic effects of strong and weak saline solutions introduced into the alimentary canal and the practical inferences to be deduced therefrom, as to the use of saline cathartics and diuretics, also the endosmotic or exosmotic effects of water and of saline substances introduced into the blood, on the blood corpuscles. 97.

What appear to be the relative functions of the absorbent and sanguiferous vessels in the absorption of nutritive and other substances from the alimentary canal; what difference exists in this respect between vertebrated and invertebrated animal; and how far may the act of absorption be explained on physical principles? 100.

State the properties of chyle, and point out the differences between the composition of that fluid and of the blood. 101.

Compare and contrast the physical and chemical properties of chyle, lymph, and blood. 104.

Give an account of the structure of lymphatic vessels, describing their structure, and that of a lymphatic gland, their mode of origin, general course, and termination. 102.

What are the probable functions of the absorbent system, as inferred from its structure, its distribution, and its comparative anatomy, as well as from experimental investigation? 104.

BLOOD.

Give an account of the red corpuscles of the blood, describing their figure, size, structure, and chemical nature, with the chief differences they present in different vertebrated animals; state also what is the average proportion of red corpuscles in human blood, and what variations are observed according to age, sex, and other circumstances. 107, &c.

Describe the physical and chemical characters of the blood in man, and the changes it undergoes when removed from the course of circulation both within and without the body; and state the conditions by which its coagulation is effected in either case respectively. 116.

Enumerate the principal proximate constituents of the blood, and of muscle; give the empyric or elementary formulæ of those constituents; and state to what substances the alkalinity of blood and the acidity of muscle may be ascribed. 116.

State the proximate chemical composition of the human blood, and point out the differences between arterial, ordinary venous, and portal blood, and the cause of these differences. 118.

Give an account of the histological structure of the heart—its movements, and the mechanical import of its different parts—in the adult, and describe the changes which it undergoes in the fœtus. 126.

Give an account of the principal theories that have been proposed to explain the coagulation of the blood. What appears to you the most probable? And why? 120.

CIRCULATION.

Describe the form, structure, and connexions of the different valves in the heart and great arteries, and explain briefly the mode in which they perform their office. 120.

Describe the structure and explain the mechanism of the different valves placed between the auricles and the ventricles of the heart, at the orifices of the aorta and pulmonary artery, and in the veins. What veins are known to be destitute of valves, and in what veins are they most numerous? 127.

What is the nature of the arterial pulse; and what are the conditions which (within the range of ordinary health) have most influence upon its rate and character? 136.

Give an account of the structure and properties, physical and vital, of a middle-sized artery. 138.

Give an account of the structure of the walls of the larger and smaller arteries, veins, lymphatics, and capillaries. 138.

In what manner is the circulation of blood through the arteries modified by the properties of their walls? 141.

Describe the distinctive structural peculiarities of the arteries, capillaries, and veins in man. In which of the lower animals are there no capillaries, the arteries and veins being united by "lacunæ" or by the general cavity of the body? 143.

Describe the circulation of the blood through the capillaries at the periphery of the body, and the agencies by which it is sustained. 145.

How do the veins commence, and where do they terminate? What is peculiar in the vena porta? Describe the structure and mechanism of the valves of the veins, and explain by what means the blood is moved through these vessels? 148.

In what manner and degree does the velocity of the blood's motion differ in different parts of the sanguiferous system; and to what causes are these differences to be ascribed? State what you conceive to be the forces by which the impulsive power of the heart is assisted, modified, or resisted, in the several parts of the vascular system. 149.

RESPIRATION.

What is the structure of the trachea, bronchi, and pulmonary cells? Describe the mechanism of the respiratory act, and the changes undergone by the air inspired. 151.

Describe the ultimate structure of the human lung; explain the mechanism of inspiration and expiration; and give an account of the physical process by which the exchange of gaseous constituents between the blood and the atmosphere is effected. 153.

Give an account of the mechanism of respiration in man; enumerating the muscles and nerves chiefly concerned in the respiratory movements, the action of each, and the nature and degree of the resistance to be overcome; stating the proportion of the whole volume of air in the lungs which is renewed at an ordinary act of respiration; and showing how its entire mass is affected by this interchange. 154.

To what actions within the body does the oxygen introduced by the respiratory process ordinarily become subservient; and what are the effects of a prolonged deficiency of oxygenation upon the composition of the urine? 162.

In what way is the circulation of the blood affected by suspension of the respiratory process in a warm-blooded animal; and what is the immediate cause of death, if that suspension be continued? 166.

Give a general account of the mode in which the vital action is influenced by heat; illustrating it by examples drawn from cold-blooded animals, and from warm-blooded animals in the states of hybernation and starvation? 170.

To what orders do most of the hybernating mammals belong? Give examples; and describe the conditions of their functions during hybernation. 170.

SECRETION.

Enumerate the various excretions, indicating the average daily amount of each in a healthy adult man; and point out the sources whence they are derived, and the channels through which they are eliminated. 177.

, Arrange the secretions and excretions according to their reactions with test-paper. 181, et postea.

What are the proximate constituents of milk? Describe their chemical properties and composition. 181.

Describe the secreting structure of the liver; give an account of the composition and uses of the bile; and state what is known of the changes produced in the composition of the blood during its passage through the portal cieculation. 186.

What is ascertained as to the functions of the liver, the chemical constitution of the bile, and the uses of that secretion in the animal economy? 189.

What is glycogen? Detail the arguments for and against the position that the liver is normally a sugar-forming apparatus. 191.

Describe the principal varieties in the structure of the kidney, and in the mode in which it is supplied with blood, in the different classes of vertebrata; and give an account of the history of its development in man. 196.

What changes does the blood undergo in passing through the kidney? or, in other words, in what respect does the blood in the emulgent veins differ from that in the renal artery? How may *Professor Graham's* doctrine of dialysis be applied in explanation of the mode in which the urinary products are eliminated? Describe the muscular structure connected with the membraneous part of the urethra, and specify its action on the urethral tube. 202.

What are the proximate components of the human urine, in health, and in disease? Give the formula of their ultimate composition. 206.

What are the best means of determining the quantity of urea in healthy urine, and of saccharine matter in cases of diabetes? 208.

Describe the external and chemical characters of the varieties of urinary calculi; the composition and properties of their proximate components; and explain the chemical principles upon which the medical treatment of calculous disorders is founded. 232.

Enumerate the principal remedies employed as diuretics. Explain the different modes by which they are supposed to operate, aud the circumstances by which their selection should be determined. 234.

DUCTLESS GLANDS.

What organs of the human body may be comprehended under the name of "ductless glands?" 237.

Describe the minute structure of the spleen; the principal diversities it presents among different animals; the peculiarities of splenic blood under various circumstances; and the inferences as to the function of the organ which you would base on these facts. 237.

Describe the structure of the spleen; enumerate the other organs which, more or less, resemble it, and state in what class of animals a spleen is found. 237.

Describe the situation, form, and internal structure of the supra-renal body; also the source and mode of distribution of its blood-vessels and nerves. 240.

INNERVATION.

Give an account of the more important physical and physiological properties of nerve: under the former head include a statement of what is known with regard to the electrical phenomena exhibited by nerves, and the influence of electrical currents on innervation. Under the latter, state by what experiments the motor and sensory functions of nerves, the reflecting power of the spinal cord, and the direct influence of the nervous system upon the state of the heart and vessels have been demonstrated. Add any experimental evidence with which you may be acquainted, tending to prove the direct influence of the nervous system on secretion. 249.

Point out the essential conditions upon which the maintenance of the irritability in nerves depends; and mention experiments proving certain conditions to be indispensable. Also, describe the changes which take place in the peripheral and central portions of a divided nerve, a short time after its division. 252.

Give an account of the electric phenomena exhibited by muscles and nerves, in the state of repose and during the exercise of their functions. 255.

Describe the structure of the electrical organ found in certain fishes, and give an account of the electrical phenomena exhibited by these animals, with the views entertained as to the mode in which the electricity is developed. 256.

Describe the structure and functions of the spinal cord (not including the medulla oblongata); and state what has been determined, experimentally, with regard to the transmission of sensory and motor impressions through it. 264.

Describe the structure, obvious and microscopic, of a spinal nerve and its ganglion. By what evidence is it shown that one root of a spinal nerve is motor and the other sensory? 271.

Describe the structure of the medulla oblongata, its connexion with other parts of the encephalon and with the spinal cord, and the mode of origin of the several nerves attached to it; and state what is the present state of our knowledge of the functions of its several parts. 274.

State what you consider to be the functions of the cerebellum, and give the grounds of your belief. 278.

State what inferences as to the functions of the different parts of the encephalon may be drawn from the results of experiments on that organ, and from a comparison of its structure in different orders of animals, mentioning the principal facts on which such inferences are founded. 284.

Give an account of the sympathetic system of nerves, and define the functions over which it presides. What is its general arrangement in the different classes of vertebrate animals, and how is it represented among the invertebrate? 289.

What is the intimate composition of the ganglionic system of nerves? State the distinctive properties of organic nervous matter. In what structures is its presence to be detected, and what are its functions in the animal economy? 289.

What do you consider to be the degree of dependence of nutrition and secretion upon the nervous system; and what are the grounds of your belief? 293.

What is the evidence that particular parts of the cerebro-spinal nervous axis act as nervous centres for particular parts of the vascular system? State what is known respecting the influence of the nervous system in relation to animal heat? 293.

MOTION.

Describe the nature of ciliary action; enumerate the classes of animals in which it is the sole means of effecting the change of the respiratory medium; and state the extent to which it is employed for respiratory and other purposes in the human system. 297.

Describe the structure, chemical composition, properties, and mode of development and repair of the white and yellow fibrous tissues; and give an account of their general distribution in the human body, and of the functions to which they are respectively subservient. 298.

Give an account of the cellular or areolar tissue; describing its structure, its physical and vital properties and chemical composition, the varieties which it presents in different parts, and its mode of distribution in the body. 299.

Give an account of the structure of the adipose tissue, its distribution in the body, and the purposes it serves in the animal economy. 300.

Give an account of the physical and chemical characters, intimate structure, vital properties, and mode of nutrition of the several varieties of cartilage, including fibro-cartilage, and explain the purposes which they serve in the animal body. 301.

Give an account of the form and structure of serous membranes in general, the nature of their secretion, and the purposes which they serve. 303.

Classify the various kinds of joints in the human body, giving an instance of and describing the mechanical properties peculiar to each kind. 305.

Give an account of the minute structure and chemical composition of bone; describe the mode of its first formation and subsequent increase; and state the chief diversities which it presents in different classes of animals. 306.

What are the proximate components of recent human bone, and how are they quantitatively determined? 307.

Explain the following points respecting the non-striated muscular tissue, viz.:—the parts of the body in which it occurs, its aspect and mode of arrangement as apparent to the naked eye, its microscopic characters and the differences which it presents in different situations. 312.

Enumerate the tissues which enter into the formation of a voluntary muscle, and describe their structure, their arrangement in the muscle, their mechanical and vital properties, chemical composition and uses. State briefly the conditions and phenomena of muscular contraction. 313.

What is the structure of the different kinds of contractile tissue? State the arguments for and against the existence of a vis insita, or inherent contractile power in muscle. 313.

Analyse the process of walking in man; explaining the character of the forces which are brought into play, of the levers through which they act, and the conditions which regulate the rhythm of the natural pace of any given man. 322.

VOICE.

In what manner are the vocal sounds produced in the larynx; upon what acoustic principles may their production be explained, and in what way are they modified by the actions of the several muscles, which form part of the laryngeal apparatus? 324.

SPECIAL SENSES.

Describe the secreting apparatus of the skin, and the respective functions of its different glandulæ; and state the purposes of the cutaneous exhalation in the general economy, with the principal conditions of its variation. 337.

What is the structure of the human hair, and how is it developed? 334.

Give an account of the form, structure, connexion, and mode of growth of the nails. 333.

Give an account of that part of the integument named the "true skin;" describing its texture and chemical composition, the papillæ and furrows on its surface, the arrangement of its blood-vessels and lymphatics, and the mode of termination of the cutaneous nerves. By what means may the skin's sensibility in different parts be compared; and what is the general result of such comparison? 335.

What are the corpuscula tactus? What functions have been ascribed to them? and how may the delicacy of the sense of touch in different parts of the body be estimated? 336.

What is the nature of the muscular sense; and what share does it take in the performance of voluntary movements? 336.

Describe the origin and general distribution of the fifth pair of cranial nerves, with the attributes of its principal sub-division; and state the effects of the intra-cranial section of its trunk. 345.

What is the structure of the Human Tongue? and on what evidence do the received views as to the functions of its nerves rest? 342.

What are the nerves by which the tongue is supplied; and what may probably be inferred from their distribution, from experiment, and from pathological observation, as to their respective functions? Describe the structure and the probable uses of the different kinds of lingual papillæ, in man and other animals. 345.

Describe the structure of the organs of smell in man, noting the peculiarities of the olfactory nerve, and explaining the mechanism by which odorous particles are brought into contact with the Schneiderian membrane. 349.

Describe the structure of the eyeball, and explain the uses of its several parts. 358.

Give an account of the structure and arrangement of the choroid coat and iris; mentioning briefly the uses assigned to these parts of the organ of vision. 361.

How is the human eye adapted to distinct vision at different distances, and how does vision enable us to distinguish between superficial figures and solids? 375.

Describe and account for the various catoptric phenomena exhibited in the human eye; and the differences observed in some of these phenomena when the eye is adjusted to distant and to near vision. 376.

Why do the eyes of cats shine in comparative darkness? State what becomes of a ray of light which enters the human eye, and explain the principle of the ophthalmoscope. In what way is it possible to see the retinal vessels and the macula lutea in one's own eye? What appearances do they present? why is it possible that the "columnar layer" is the immediate recipient of luminous impressions? What are the conditions of single vision with two eyes, and of double vision with one eye? 375.

Which is the least sensible part of the receptive nervous surface of the eye, and by what experiment may it be domonstrated? 379.

Describe the osseous walls of the tympanum, and the small bones contained in that cavity. 381.

Describe the physiological effects of the section and of the irritation of the vagi nerves. 395.

REPRODUCTION.

Give an account of the phenomena classed under the head of the "alternation of generations." 399.

Describe the form, movements, and development of the spermatozoa; and state the grounds for attributing to them the essential part in the act of fecundation. 402.

Describe the mammalian ovum, and give an account of the changes which it undergoes up to and inclusive of the formation of the placenta. 405.

Describe the first formation of the sanguiferous system in the human fœtus, and the principal changes which it undergoes, up to the establishment of pulmonary respiration. 411.

Describe the structure and offices of the Wolffian bodies; and explain their relations to the genital organs. 412.

State the peculiarities of the heart, blood-vessels, and liver of the mature fœtus, by which these organs differ from their conditions in the adult. 413.

Describe the principal stages of the development of the nervous centres in the human fœtus; and state how far these correspond with the permanent forms of those organs in the lower animals.

PRINCIPLES OF DISEASE.

Describe the more important changes the blood undergoes in various acute and chronic diseases State the arguments in support of the doctrine that diseases originate from morbid blood, and give examples in illustration. 419.

Explain the occasional results of hyperemia (excess of blood), and give examples of each. 419.

Describe degeneration of arteries, and discuss the effects arising from this condition. 453.

Explain the pathology of hemorrhage, the circumstances which favour its occurrence, and its effects, local and general. 425.

Explain the term atrophy. Mention its causes, and show how they operate in producing either general decay, or atrophy of particular organs or tissues. 435.

Describe the varieties of tubercle, their relations to each other, and their terminations. 447.

Describe the process of suppuration, including an account of the various modes in which purulent formations take place. 449.

Describe the pathological characters of adenocele, its symptoms, diagnosis from other diseases of the breast, and the appropriate treatment. 465.

Describe the varieties of cancer, and the mode in which cancer affects the brain, the liver, and the stomach respectively. 473.

Enumerate the various chemical compounds used as disinfectants or deodorizers. Mention the circumstances which render their employment expedient, and describe their mode of application. "Lectures on Public Health."

Give an account of the effects of muscular exercise on the various organs, and its influence on the general health. "Lectures on Public Health."

Explain briefly the meaning of the physiological terms, chyme, chyle, sangufication, absorption, nutrition, secretion, excretion, development. Glossarial Index.

ROYAL COLLEGE OF SURGEONS, ENGLAND.

DIGESTION.

Describe the process of mastication, the muscles employed, and their respective actions. 70.

State the position and relations of the three salivary glands of the mouth, and the course of their ducts; and mention the properties and uses of the saliva. 71.

Give an account of the function of digestion, describing the changes the food undergoes in its passage throughout the alimentary canal, and the means by which these changes are effected. 80.

Describe the form, situation, blood-vessels, nerves, and structure of the pancreas. State the nature and chemical properties of its secretion, and the purposes that the pancreatric fluid is supposed to serve in the function of digestion. 84.

CIRCULATION.

Is it proved that there is a circulation of the blood in the body? if so, state the facts which prove it. 125.

Describe the arrangement of the muscular tissue of the walls of the ventricles of the heart, and describe the source and distribution of the cardiac arteries, veins, and nerves. Explain the mode in which the sounds of the heart are generally supposed to be produced. 126.

Give an account of the structure of the arteries, capillaries, and veins; and explain the part which each set of vessels takes in the circulation of the blood. Mention the views generally entertained respecting the formation of the pulse. 138.

RESPIRATION.

Describe the minute structure of the lungs; and state the changes produced by respiration in the blood, and in the respired air. 152.

Mention the agents, muscular or other, by which the function of respiration is accomplished. 73.

Describe the form, the structure, and the anatomical relations of the tonsil; and state what are its functions. 154.

What muscles raise the soft palate? To what extent is it elevated in deglutition? 75.

Where is the chyle formed, what is the mode of its absorption, and how is it conveyed into the blood? 100.

State the different modes in which absorption is believed to take place, and give an account of the functions which are ascribed to the mesenteric glands, and to the absorbent glands in general. 100.

Mention the different forces that move the blood both in the arteries and veins in man. What is the arterial pulse? 136.

Describe the structure of the larger and smaller arteries and of the capillary vessels, and their respective offices in circulation and nutrition. 138.

Describe the mechanism of respiration; the changes which take place in the form and size of the chest, and in the lungs; and give a short account of the agencies by which these changes are effected. The origin and insertion of muscles, and the chemistry of respiration are not included in this question. 154.

What are the phenomena of an ordinary inspiration and expiration? 154.

What is the average number of respirations in a minute during health? What is the average amount of air inspired at each inspiration? What is the average extreme capacity of the lungs for air in man, as tested by a forcible expiration following a deep inspiration? 157.

Upon what nerves is the impression made, and by what nerves is the notice transmitted to the cerebro-spinal axis, by which the act of coughing is induced? Is the effort voluntary or involuntary, and how is its nature in this respect designated by physiologists of the present day? And what are the muscular actions by which a forced or abrupt expiration is effected? 157.

Give a brief physiological explanation of the following actions:—Coughing. Sighing. Sneezing. Vomiting. 157.

State the composition of the air we breathe, and the changes which the air and the blood undergo in their passage through the lungs. 162.

SECRETION.

Enumerate the blood-vessels of the liver; mention the parts from which they severally arise; and describe the uses of the different vessels. 184.

Give the chemical composition of bile; and state the purposes which this secretion is believed to effect both with regard to digestion and to the general system. 187.

Describe the structure of the kidney, and state the chemical çomposition of the urine. 196.

What are the causes assigned for the redundancy of lithic acid in the urine? How is the excess ascertained? What are the injurious effects, if the excess continue? And what is the treatment of such excess, prophylatic and curative? 211.

What is hæmaturia? Mention the sources from which the blood may be derived in such cases, and state the symptons on which your diagnosis would be formed. 226.

INNERVATION.

Mention the principal situations in which nervous ganglions are found; describe their external appearance and internal structure; and, finally, state their supposed functions. 250.

Describe the structure, attachments, and processes of the dura mater. State also the situation and uses of the several sinuses connected with it. 259.

If the tunica arachnoides be considered to form the serous cavity of the cerebro-spinal axis, what is its disposition and extent? 259.

State the peculiarities of the cerebral circulation, and describe the structure and arrangements of its arteries and veins. 260.

Describe the peculiarities of the circulation of the blood in the brain; and state the reasons assigned for the peculiarities in the form, structure, and disposition of the vessels, both afferent and efferent. 260.

In what respects do the blood-vessels carrying the blood from the brain differ from veins generally? What reasons can you give for the peculiarities observed in the sinuses of the dura mater? 263.

Describe the structure of the cervical portion of the spinal marrow, and the origin of the different nerves which arise from it. 264.

MOTION.

What bones are tied together by yellow ligaments? Describe their structure and functions. 298.

Describe the composition and minute structure of bone. Describe also the original formation of the flat bones, such as the parietal, and of the long bones, such as the humerus. 306.

Enumerate the different kinds of cartilage that exist in the human body; describe the peculiarities of intimate structure that distinguish each variety, and state the purposes which each answers. 301.

Describe the minute structure of muscular fibre. 312.

Mention examples of muscles of the body acting as levers of each kind, and state the reason for the large preponderance of those acting as levers of the third kind. 320.

VOICE.

What are the functions of the epiglottis? Explain how the opening of the glottis is closed. 324.

Describe the cartilages, ligaments, and muscles of the larnynx, stating their relative connexions and uses. 324.

SPECIAL SENSES.

Enumerate the structures which compose the skin, and describe its functions. 332.

Describe the formation, composition, properties, and uses of the epidermis. 333.

Describe the minute structure and mode of formation of the cuticle nails and hairs. 333.

Describe the distribution, and generally supposed functions, of the nerves of the tongue. 345.

Describe the course, relative connexions, final distribution and functions of the 3rd and 1st division of the 5th nerves, beginning with an account of their entrance into the orbit. 346.

Describe the structure, connexions, and uses of the iris. Give a description also of its blood-vessels and nerves. 364.

Describe the distribution of the several nerves which go to the nose. 349.

Describe the structure and functions of the eyelids, with their muscles and nerves. Describe also the lacrymal apparatus and the course of the tears. 353.

What are the actions of the muscles of the globe of the eye? 354.

Describe the tympanum, its position in the ear, its boundaries, the foramina, and eminences seen on its walls. Describe the ossicula, and the muscles attached to them. 381.

Describe the Eustachian tube, its composition, situation, direction, length, the size of its tube, its openings, and use. 383.

Describe the origin, connexions, distribution, and functions of the spinal accessory nerve. 394.

REPRODUCTION.

Describe the structure of the placenta; state the changes which the fœtal blood undergoes by circulating in this organ, and the mode by which those changes are effected. 410.

Describe the circulation of the blood through the fœtal heart. 413.

PRINCIPLES OF DISEASE.

Describe the processes by which simple and compound fractures are united; and state the periods which they usually occupy. 440.

Describe the signs of inflammation in an external part. Describe also the state of the vessels and the blood in a part which exhibits the signs of a fully developed inflammation. And describe what changes take place in "resolution" of the inflammatory attack. 443.

Describe the mode of union in the case of an incised wound. Describe how far the process may be considered inflammatory, whether the union may be effected without any marks of inflammation, and in what manner inflammation may interrupt the process of union. 438.

ARMY MEDICAL DEPARTMENT.

EXAMINERS—*Professors Paget, Busk, Parkes, and Hooker.*

INTRODUCTION.

What are the principal modifications of cell-structure in the animal and vegetable kingdoms? Give some examples of morbid cell-development in the animal system. 13.

NATURAL HISTORY OF MAN.

What are the prominent differences between the skeletons of simiadæ and man? 18.

Describe the vertebral column, its relations and functions. Define a typical vertebra in the terms employed by *Professor Owen.* 24.

Describe a typical vertebra in the language employed by *Prof. Owen,* and point out in accordance with this the homologies of the atlas, axis, and third cervical vertebra. 25.

What are the principal modifications of the skull in the races of man? 32.

What are the principal races of man; how are they distinguished and distributed over the surface of the globe? 33.

Enumerate the five principal races of man; give their distinctive characters and native countries. 33.

CHEMISTRY OF MAN.

What are meant by proximate principles in plants and animals? Give examples and state their chemical composition. 45.

State concisely the general distinctions, structural, physiological, and chemical, between the animal and vegetable kingdoms. 51, et postea.

In what parts of the animal system does phosphorus exist, and in what states of chemical combination? 41.

Give briefly the characters and properties of protein, fibrin, gluten, starch, casein, elain, stearin, and legumin. 46.

DIGESTION.

Mention the principal heads under which alimentary substances may be arranged, and give one or more instances of substances belonging to each group. 52.

What is meant by nitrogenous principles in food? Give examples of nitrogenous and non-nitrogenous foods. 52.

Which is most nutritious, rice-flour or pea-flour? Upon what do their relative qualities as articles of diet depend? 57, and "Lectures on Public Health."

To what constituents are the nutritious properties of wheaten bread due? Give their chemical composition, and explain the changes they respectively undergo during the operation of mastication and digestion. 58.

Describe the different kinds of epithelium and where they occur; and state particularly on which or on what parts of the mucous membrane ciliated epithelium is found. 64.

Describe the mucous membrane in the various divisions of the alimentary canal, commencing at the mouth. 64.

Describe the order of succession of the teeth at different periods of life, and the mode in which they are developed in the fœtus. 69.

Give an account of the structure of the submaxillary and sublingual glands, and of the composition and physiological properties of their secretion, noticing how far the latter agree with or differ from those of the parotid secretion. 71.

How is starch converted into sugar in the animal economy? 73.

Describe minutely the structure and functions of the mucous membrane of stomach. 77.

Describe the processes of digestion and absorption of bread, meat, and milk. 80.

Describe the process of digestion in man pointing out particularly the functions of the liver and the purpose of biliary secretions, and state what changes are apparent in the chyle, after it has passed through the mesenteric glands. 84.

Write diet-tables, such as you may have seen in any hospital, distinguishing "Full Diet," "Half or Middle Diet," and "Low Diet." 60.

Describe the duodenum; the structure of its various coats; its vessels, nerves, relations to other parts, and its physiological function. 87.

Give a full account of the structure and physiological functions of the duodenum and pancreas. 84.

Describe the process and products of digestion and the mode in which the latter are disposed of. 81.

Give a description of the cœcum and the illio colic valve; and state the difference in point of structure between the large and small intestines. 90.

Name and describe briefly the form and indicate the site and distribution of the minute glands which compose or are found in the mucous membrane of the alimentary canal. 88.

ABSORPTION.

Give a general account of the lacteal and lymphatic systems, including the minute structure of the lymphatic vessels and glands. 99.

Give an account of what is known respecting the structure and functions of the lymphatic glands. 102.

Describe the mode in which the absorption of different substances is effected in the stomach and intestines, indicating also the course of the chyle and the changes it undergoes in its passage to the blood. 100.

BLOOD.

Describe the human blood, its physiological, physical, and chemical properties; the mode of development of the corpuscles; and mention the distinctive peculiarities of the blood in various other mammals, in birds, fishes, and reptiles. 107.

Describe the process of coagulation of the blood, noticing the principal explanations of it that have been offered, and the conditions by which it is hastened, retarded, or prevented, within or without the body. 118.

CIRCULATION.

Describe the mechanism of the heart's action; the sounds attending it, and their cause. 127.

What are the conditions upon which the rhythmical movements of the heart depend, and to what causes are its sounds due? 133.

Give an account of the structure and properties, physical and vital, of a middle-sized artery, and of the capillary vessels. 138.

Describe the structure of the walls of the larger and smaller arteries, veins, lymphatics, and capillaries. 138.

RESPIRATION.

Describe the minute structure of the human lung and the nature of the respiratory process. 152.

Under what circumstances or what conditions of age, sex, stature, or configuration of the chest is the extreme inspiratory capacity (vital capacity) of the thorax augmented or diminished? and mention the average inspiratory capacity of a healthy man about 5 feet 10 inches in height. 159.

State precisely how, and to what extent, air is vitiated by respiration and cutaneous transpiration; what quantity of air is required by a healthy adult in a given time, and how this air can be best supplied. 162, and "Lectures on Public Health."

What are the mechanical and chemical constituents of the atmosphere; and in what way does an excess of any of these constituents affect the human frame? 162.

Mention the circumstances which increase or diminish the amount of carbonic acid exhaled by animals. 163.

What noxious gases are most frequently met with in nature, and what are their effects on animal life? 165, and "Lectures on Public Health."

What are the physiological effects in man of suspended or deficient respiration? 166.

Indicate the sources of heat in animals, the circumstances by which it is augumented and diminished, and the means by which it is prevented rising beyond a certain point. 171.

To what orders do most of the hybernating animals belong? Give examples: and describe the condition of their functions during hybernation. 170.

SECRETION.

Arrange the secretions and excretions relative to their re-action with test-paper. 181, et postea.

Enumerate the various excretions, indicating the average daily amount of each in an adult man; and indicate the sources whence they are derived and the channels through which they are eliminated. 177.

Describe the minute structure of the liver and the functions of that organ. 184.

Describe the minute anatomy and the functions of the kidney, noticing the sources whence the principal elements contained in its secretion are derived. 197.

Describe the characters and tests of the following deposits in urine: lithic acid, triple phosphate, oxalate of lime, mucus, pus. 210.

Describe the microscopic characters of the following urinary sediments: ammoniaco-magnesian phosphate, uric acid, cystine, granular, and hyaline casts, renal epithelium, and blood. 210.

Under what circumstances is sugar found in the urine of men? 219.

What are the microscopic characters of yeast, starch, milk, and blood? 220.

Enumerate some of the principal diseases in which albumen may be found temporarily or permanently in the urine. 225.

What are the principal diseases attended with discharge of pus in the urine? and how may they be severally distinguished. 226.

DUCTLESS GLANDS.

Describe the minute anatomy of the spleen, and the peculiarities of splenic blood. 237.

INNERVATION.

Describe the minute structure of the white and grey substances of the brain. 248.

Describe the nervous and muscular tissues, distinguishing the different kinds of each, with the functions assigned to each respectively. 248, et postea.

Describe the structure of a nervous ganglion. 250.

Describe the anatomical structure of the spinal cord and its physiological relations. 264.

Describe what is meant by "reflex action" as applied to the nervous system; and give instances of the various phenomena attributed to its influence. 267.

State the usual direct and remote consequences of fracture of the spine, with crushing of the spinal cord in the lower part of the cervical region and explain them physiologically. 270.

What are the immediate and remote effects of the division of the lateral half of the spinal cord in the dorsal region? 270.

Describe the minute structure and functions, so far as they have been determined by experiments of the spinal cord and medulla oblongata. 274.

Point out the situations of the ganglia of the sympathetic in the head and neck, and describe their connexions with other nerves. 289.

MOTION.

Give the physical and chemical characters of yellow elastic tissue, and notice the principal situations in which it exists in the human body. 298.

Describe the structure of the permanent cartilaginous tissues in the human body, noticing the parts in which they occur, and the uses to which they are subservient. 301.

Describe the principal morbid changes to which articular cartilages are liable. 302.

Classify the various kinds of articulation, giving an instance of, and describing the motions peculiar to each kind. 305.

Describe the minute structure and modes of development of bone. 308.

SPECIAL SENSES.

Describe the structure and functions of the skin; indicating the principal differences existing in various parts of the body. 332.

Describe the lachrymal apparatus. 354.

Describe and explain the symptoms of complete paralysis of one of the 3rd or oculo-motor pair of nerves. 357.

Describe the minute structure of the sclerotic, cornea, and iris. 358.

Describe the physiological effects of division or injury of the portio dura above the point where it gives off the chorda tympani nerve. 394.

Describe the structure of the retina. 368.

Give a full account of the anatomical and physiological relations of the pneumogastric nerves. 395.

Describe the physiological effects of the division of the vagi nerves. 396.

What is the cause of the suffocation which usually supervenes upon division of the inferior laryngeal nerves, or of the trunk of the pneumogastric nerve above those branches? and state what muscles of the larynx are supplied with motor power by the superior laryngeal nerve. 396.

REPRODUCTION.

What is meant by the alternation of generations? How are plants distinguished from animals, and both from inorganic substances? 399.

Describe the structure of the "ovum" in the bird and mammal; and the essential conditions of impregnation. 405.

What are the decidua, chorion, amnion, and vesicula umbilicalis, and describe their relations to the fœtus in the human subject. 409.

Give an account of the mode of development of the kidney, from the earliest period; do the same also with respect to the testis.

Mention the properties by which living bodies and tissues are distinguished from dead. 417.

PRINCIPLES OF DISEASE.

Enumerate the better known abnormal, chemical, and physical alterations of the blood. 419.

What are the causes of enlargement of the spleen? How would you recognize such enlargement? What microscopical conditions of blood may be coincident with it?. 422.

What are the most usual views now held of the nature and consequences of thrombosis and embolism? 428.

What are the chief causes of blocking up blood vessels (arteries and veins); and what are the results of blockage of arteries at the base of the brain, of the pulmonary arteries, and of femoral veins. 428.

Describe the processes by which hemorrhage from a completely divided artery may be naturally arrested, and those which follow the tying of an artery so divided. 441.

Describe the states of the circulation in the conditions named respectively: active congestion, passive congestion, and acute inflammation, as exemplified in the eye or skin. 442.

Describe the phenomena of inflammation as seen with the naked eye, in consequence of a foreign body, such as a small fragment of metal, lodged in the substance of the cornea. 443.

Describe and compare the principal effects of acute inflammation in the mucous, serous, and synovial membranes, taking for instances the conjunctiva, tunica vaginalis, and synovial membrane of the knee. 446·

Describe "union by the first intention," and state the best means of promoting it. 438.

Describe the process of healing by granulations, and some of the most frequent appearances of unhealthy granulations. 438.

Describe the chief varieties of pus; such as are called laudable, sanious, ichorous, strumous, &c. Mention their principal microscopic characters, and what they severally indicate. 449.

Describe the process for the separation of a slough of the integument, and that for the healing of the surface exposed by its removal. 452.

What are the chief conditions, independently of direct injury by violence, in which gangrene of the lower extremities occurs? Describe particularly the state of the blood vessels and their contents above the gangrenous part. 452.

In the case of a patient with fracture of the spine and complete crushing of the spinal cord in the lower dorsal region, what evils may be expected to ensue in the paralysed parts, and how may they best be prevented or remedied if they occur. 452.

Enumerate the principal entozoa which infest the human subject, and state what you know of their habits. 488.

Define the terms catalysis, dialysis, fermentation, amalgamation, hybernation, endosmose, crystallization, idiosyncrasy, psychology, ontology. Glossarial Index.

GLOSSARIAL INDEX.

ABDOMEN (*abdo*, I conceal.) The cavity containing the digestive organs.

ABDOMINAL RESPIRATION. 154.

ABDUCTION. A motion by which one part of the body is removed from another. 305.

ABERRATION chromatic. False colouring of an optical image. 376.

ABERRATION spherical. Indistinctness of vision, caused by formation of images on the front of the lens. 376.

ABNORMAL (*ab*, from; *norma*, a rule). Unnatural diseases.

ABORTION. The expulsion of the fœtus before the seventh month.

ABSCESS (*abscedo*, I depart from). A collection of pus.

ABSORBENTS (*absorbeo*, I suck up). The lacteals and lymphatics. 99.

ABSORPTION. The imbibition of fluid. 94.

ABSORPTION, Interstitial.

ACARDIAC (ἀ, not; *καρδια*, a heart). Without a heart. 135.

ACARUS SCABIEI. The itch mite.

ACCIDENTAL elements. 38.

ACEPHALOUS (ἀ, not; *καφαγη*, a head). Without a head.

ACETABULUM (a saucer). The cavity for the reception of the head of the thigh bone.

ACHROMATISM (ἀ, not; *χρωμα*, colour). The production of images without the decomposition of light. 376.

ACNE. A papular eruption.

ACOUSTICS (*ακουω*, I hear). The science which treats of the phenomena of sound. 388.

ACROMION (*ακρος*, high; *ωμος*; shoulder). The highest process of the scapula.

ACTUAL CANTERY. Burning by heated instuments.

ACUPUNCTURE (*acus*, a needle *pungo*, I prick). The operation of puncture with a needle

ACUTE DISEASES. Violent and rapid.

ADAPTATION of the eye to vision at varying distances. 375.

ADDUCTION (*adduco*, I draw to). The act of drawing towards. 305.

ADENITIS (*αδην*, a gland; *itis*, denoting inflammation). Inflammation of a gland.

ADENOID, resembling a gland.

ADHESIVE INFLAMMATION. 446.

ADIPOCERE (*adeps*, fat; *cera*, wax). A peculiar waxy substance produced in animal bodies by the evolution of their nitrogen; Grave wax. 453

Adipose tissue. Tissue containing fat. 300.

Adventitious products. 447.

Adynamic (ἀ, not; δυναμις, power). Powerless.

Ægophony (αιξ, a goat; φωνη, voice). A peculiar sound of voice, audible in the chest in some diseases.

Aerated bread. 58.

Aeration (αηρ, air). Exposure to the air or gases. 162.

Afferent Nerves (*affero*, I bring). Nerves that carry sensation to the centres. 267. Those vessels entering the Malpighian tufts. 197.

After birth. The fœtal appendages. 414.

After Sensations. 340.

Age, in relation to pulse. 137.

Aggregate or Agminate Glands, intestinal glands described by Peyer. 89.

Ague cake. The enlarged spleen. 422.

Air. Composition of, 161—amount of respired, 158—changes of in respiration, 162.

Air Cells of lungs. 152.

Albino (*albus*, white). An animal in which all pigment is absent in skin, hair, or eyes. 364.

Albumen. A proximate principle of organic bodies, 46—its relation to fibrin, 114.

Albuminoids. Substances resembling albumen, the protein compounds. 45.

Albuminuria. 222.

Alcohol. As food, 53—its influence on respiration, 163.

Aliment (*alo*, I nourish). Food. 51.

Alkali. A substance having the property of neutralizing acids, and turning vegetable blues to green.

Alkalies of blood. 116.

Alkaloid Substances. Such as morphia, analogous to alkalies.

Allantois (ἀλλας, a sausage; ειδος, like). One of the membranes of the fœtus. 412.

Allotropism. The capability of existing in two or more chemical or physical states.

Alopecia (ἀλωπηξ, a fox). Baldness.

Alto. A variety of female voice. 328.

Alveolus. A cell or socket; the cavity for a tooth. 69.

Alveoli, of Stomach. 77.

Alvine (*alvus*, the belly). Belonging to the belly.

Amaurosis (ἀμαυρος, dark). Blindness from defect or loss of power of nervous system. 485.

Amblyopia (ἀμβλυς, dim; ωψ, the eye). Dim vision, or slight amaurosis.

Amenorrhœa (ἀ, not; μην, a month; ρεω, I flow). Absence of the menstrual secretion. 420

American Indians. 35.

Ammonia in the blood, 121—cyanate of, 207—urate of, 210.

Amnion (ἀμνιον, a bowl). A membrane of the fœtus. 412.

Amorphous (ἀ, not; μορφμ, form), shapeless.

Amphiarthrosis (ἀμφις, on both sides; αρθρον, a joint). A form of joint with slight motion. 305.

AMPHIBIOUS (*βιος*, life). Living under two different conditions.

AMPHORIC (*amphora*, a pitcher). Applied to a peculiar sound, like one speaking into an empty pitcher.

AMPULLÆ. The dilated portions of the semi-circular canals in the ear, 385; the dilated lactiferous ducts in the mamma. 180.

AMYLACEOUS SUBSTANCES (*amylum*, starch). Bodies resembling starch, 42—digestion of, 84.

AMYLOID. Resembling starch.

ANÆMIA (*ἀ* not; *αἱμα*, blood). Want of blood. 420.

ANÆSTHESIA (*ἀ* not; *αἰσθανομαι*, I feel). Loss of feeling or sensation.

ANALOGY (*ἀναλογια*, an agreement). Functional similarity.

ANASARCA (*ἀνα*, through; *σαρξ*, flesh). Effusion of serum into the general cellular tissue of the body.

ANASTOMOSIS (*στομα*, a mouth). A direct communication between vessels as by open mouths. 141.

ANATOMY (*ἀνα*, asunder; *τεμνω*, I cut). The science which treats of the structure of organized beings.

ANCHYLOSIS (*ἀγκυλεω*, I bend). An immovable state of a joint.

ANENCEPHALIC (*ἀ*, not; *εγκεφαλον*, the brain). Without brain.

ANEURISM (*ανα*, through; *ευρυνω*, I widen). A dilation of an artery from disease or injury of its coats.

ANEURISM by anastomosis. 467.

ANFRACTUOSITY (*anfractus*, a winding). Irregularities of surface usually applied to brain. 283.

ANGINA PECTORIS. A painful chest disease.

ANHYDROUS (*ἀ*, not; *ὑδωρ*, water). Without water.

ANGIOLEUCITIS (*ἀγγειον*, a vessel; *λευκος*, white). Inflammation of the lymphatics or white vessels.

ANIMAL, characters of an, 51—food, 54—heat, 168.

ANODYNE (*ἀ* not; *οδυνη*, pain). A medicine which relieves pain.

ANOMALOUS (*ὁμαλος*, equal). Irregular, a departure from a general rule.

ANOPLOTHERIUM (*ἀ*, not; *ὁπλον*, a weapon; *θηριον*, a beast). A pachydermatous fossil animal without organs of defence. 20.

ANOREXIA (*ὀρεξις*, desires). Loss of appetite.

ANTERIOR pyramids of medulla oblongata. 274.

ANTHELMINTIC (*ἀντι*, against; *ἑλμινς*, a worm. Capable of destroying entozoa or internal worms.

ANTHROPOID (*ανθροπος*, a man). Resembling man. 18.

ANTHROPOLOGY. The science which concerns itself with mankind. 17.

ANTIPERISTALTIC ACTION. 90.

ANTISEPTIC (*σηπω*, I separate). Preventing putrefaction.

ANTISPASMODIC (*σπαω*, I draw). Preventing or stopping spasm.

AORTA (*ἀειρω*, I carry). The vessel which carries arterial blood from the heart. 141.

Aortic Valves. 128.

Apnoea (ἀ, not; *πνεω*, I breathe Suspension of breathing. 165.

Aponeurosis (*απο*, from; *νευρον*, a nerve or tendon. A fibrous expansion or fascia. 298.

Apophysis (*απο*, from, *φυω*, I grow). A prominence from the surface of a bone. 311.

Apoplexy (*πλησσω*, I strike). Loss of consciousness and voluntary motion from a cerebral lesion.

Aqua Morgagni. Fluid supposed to exist within the capsule of the crystalline lens. 367.

Aqueductus Cochleæ. A canal leading into the cochlea. 386.

Aqueductus Fallopii. The passage for the transmission of the portio dura nerve.

Aqueductus Vestibuli. A canal transmitting a vein from the vestibule. 394.

Aqueous Humour. The fluid occupying that portion of the eyeball in front of the lens. 366.

Aqueous Food. 52.

Arachnoid (*αραχνη*, a spider's web). The serous membrane covering the brain. 259.

Arbor-vitæ. 277.

Archencephala (*ἀρχος*, chief; *εγκεφαλος*, the brain). The highest sub-class of mammalia according to *Owen*, including man only. 17.

Archetype (*αρχη*, a beginning; *τυπος*, a type). A model. 25.

Arciform (*arcus*, a bow). Curved, applied to some fibres in the medulla oblongata. 274.

Arcus senilis. A fatty ring round the cornea indicative of degeneration.

Area Pellucida. Part of the germinal vesicle. 409.

Areolar Tissue. The connective tissue, consisting of interlaced fibres of white and yellow fibrous tissues. 299.

Artery (*αηρ*, air; *τηρεω*, I keep). A vessel carrying red blood from the heart. 138.

Arterial Blood, properties of. 118.

Arteries, structure of, 138—elasticity of, 141—irritability, 142—force of blood in, 135.

Arthrodia (*αρθροω*, I articulate). A movable articulation between bones with flat surfaces. 305.

Arthritis. Inflammation of joints, generally applied to gout.

Articulata (*articulus*, a joint). That division of the animal kingdom consisting of jointed invertebrate animals.

Articulate Sounds. 329.

Arytenoid Cartilage (*ἀρυταινα*, a pitcher). One of the cartilages of the larynx. 323.

Ascites (*ασκος*, a leather bag). A collection of fluid in the abdomen.

Asphyxia (ἀ not; *σφυξις*, the pulse). Suffocation; formerly failure of the pulse. 165.

Assimilation. The process by which our food is converted into living tissue. 244.

Asthenia (ἀ, not; *σθενος*, strength). Weakness, want of strength.

Asthma (*ἀω*, I blow). Spasmodic dyspnœa. 156.

Astringent (*stringo*, I bind). Contracting, binding. 98.

Atavism. The transmission of a peculiarity from grand-parent to grandchild. 416.

Atelectasis (τελος, an end; εκτεινα, I stretch). Imperfect expansion. 158.

Atheroma (ἀθηρη, porridge). A pulpy substance found in diseased arterial coats.

Atrophy (ἀ not; τρεφω, I nourish). Wasting or want of nourishment. 435.

Auditory Meatus, external, 381—internal, 387.

Auditory Nerve. 387.

Auricle. The external ear, 380—of the heart, 127.

Automatic Action. 270.

Axis Cylinder of nerve fibre. 249.

Azote or Nitrogen. 165.

Balanitis (βαλανος, the glans penis). Inflammation of the glans penis.

Barytone (βαρυς, heavy). A variety of male voice intermediate between bass and tenor. 328.

Basement Membrane. 64.

Bass. The lowest variety of the male voice. 328.

Bicuspid (*bis*, twice; *cuspis*, a spear). Two-pointed teeth. 66.

Bifurcation (*bis*, twice; *furca*, a fork.) Binary division.

Bile. Analysis of, 187—quantity of, 187—uses of, 189.

Biliphæin (*bilis*, bile). The bile pigment or coloring matter. 49.

Biliverdin (*viridis*, green). A supposed green colouring matter in the bile. 188.

Bilifulvin (*fulvus*, yellow). A variety of bile pigment of a yellow colour. 49.

Bimana (*bis*, two; *manus*, hand). Two-handed, an order of mammalia including man only. 17.

Bladder, Urinary. 203.

Blephrospasmus (βλεφαρον, eyelid; σπαω, I draw). A spasmodic closure of the eyelids, usually seen in strumous ophthalmia.

Blennorrhœa (βλεννα, mucus; ρεω, I flow). A mucous discharge, a term used for gonorrhœa

Blood, 105—analysis of, 116—coagulation of, 118—corpuscles, 107—force of, 135—physical characters, 107—quantity, 136—velocity, 136—venous, 118—vital properties of, 118.

Bone. Structure of, 308—chemical composition, 306—mineral matter, 306—repair of, 260.

Brachial (*brachium*, the arm), belonging to the arm.

Brain. Analysis of, 247—circulation in, 260—fats of, 247—development, 411.

Branchiæ, or gills; the ærating organs of fishes.

Bread. 58.

Breathing or Tidal air. 158.

Bronchial Tubes (βρογχος. the windpipe). The secondary divisions of the air tubes. 152.

Bronchophony (φονη, sound). The sound produced by the passage of air through the bronchi.

Bronchotomy. The operation of opening the air-passages.

Bruit Musculaire. The sound of muscular contraction. 131.

Brunner's Glands. Small glands in the duodenum. 88.

Buccal Glands. 71.

Buccinator (*buccina*, a trumpet). The muscle that compresses the air in the mouth when blowing wind instruments. 346.

Buffy Coat of blood. 122.

Bursæ. Synovial sacs to obviate friction on prominent bony points. 304.

Cachexia (κακος, bad; ἕξις, habit). A deranged state of the constitution.

Cacoplastic (πλασσω, I form). Badly organizable. 447.

Cæcum (*Cæcus*, blind). The commencement of the large intestine. 90.

Calamus Scriptorius. A groove in the fourth ventricle. 277.

Calcium. Fluoride of, in bones. 40.

Calorific Digestion, 84—food, 52.

Calculi. Concretions formed in internal cavities. 232.

Calyces of kidney. 196.

Calyciform papillæ of tongue. 342.

Canaliculi. The minute canals in bones. 308.

Canal of *Petit*. A canal between the layers of the hyaloid membrane as it splits to enclose the lens. 364.

Cancer (καρκινος, a crab), so named because the processes or veins spread out like claws; malignant disease. 473.

Cannula (dim. for canna, a reed), a tubular surgical instrument introduced with a trocar or stilette.

Canthus. The angle of the eye. 354.

Capillaries. (Capillus, a hair), the most minute blood vessels. 143.

Capillary Attraction. 94.

Capillary Force. 146.

Capsule of *Glisson*. 184.

Cardia. The upper opening of the stomach. 76.

Cardiac Valves. 127.

Carotid (καρα, the head; οὖς, the ear). The artery which supplies the head and neck.

Cartilage (*cartilago*, gristle). A peculiar animal tissue consisting of a gelatinous substance called chondrin and lime salts. 301.

Casein (*caseum*, cheese). A proximate animal principle derived from milk; one of the albuminoid bodies. 47.

Catalepsy (κατα, down; ληψις, a seizing). Loss of consciousness with fixity of the extremities. 484.

Catalysis (λυω, I loosen). A term applied to certain chemical phenomena in which changes in the composition of substances are effected by the presence of another body which remains unaltered.

Catarrh (καταρρεω, I flow down). Inflammation of the mucous membrane.

Cathartics. Medicines which purge. 98.

CATHETER (*καθιημι*, I thrust into). A tubular instrument passed into the bladder.

CATOPTRICS (*κατοπτρον*, a mirror). The phenomena of reflected light.

CATOPTRIC TEST. A test for the soundness and transparency of the crystalline lens by the position of the reflected images of a candle. 377.

CAUDAL (*cauda*, a tail). Relating to a tail.

CAUDA EQUINA. The termination of *medulla spinalis.* 264.

CAUCASIAN RACE. 33.

CELL. A simple bag consisting of cell wall and contents. 13.

CELLULAR TISSUE. More properly areolar 299.

CELLULOSE. A vegetable principle resembling starch. 42.

CENTRIFUGAL (*centrum*, the centre; *fugio*, I fly). Applied to efferent or motor nerves. 252.

CENTRIPETAL (*peto*, I seek). Seeking the centre; applied to afferent or sensitive nerves. 252.

CENTRUM OVALE. The large white surface seen on removing the upper portion of the cerebral hemispheres.

CEREBELLUM. 277.

CEREBRUM. The brain. 282.

CERUMINOUS GLANDS. Those that secrete the wax in the external ear. 381.

CERVICAL. Pertaining to the neck, —vertebræ, number of, 27.

CHEMOSIS (*χαινω*, I gape). A turgid and raised state of the conjunctiva.

CHIASMA. The commissure of the optic nerves, so called from its resemblance to the Greek letter, χ. 371

CHLORIDE of Sodium. 40.

CHLORINE (*χλωρος*, greenish yellow). A yellowish elementary gas. 38.

CHLOROSIS. A disease of the blood in young females, characterised by a greenish color of the skin. 420.

CHOLAGOGUE (*χολη*, bile; *αγω* I lead). A medicine which causes evacuation of bile. 98.

CHOLEIC ACID. An acid of bile. 188.

CHOLERA (*χολη*, bile; *ρεω*, I flow). Blood in cholera. 421.

CHOLESTERIN (*χολη*, bile; *στερεος*, solid). The fat of bile. 44.

CHONDRIN. The proximate animal principle of cartilage. 48.

CHORION (*χωρεω*, I contain). One of the membranes of the fœtus. 410.

CHOROID MEMBRANE. One of the coats of the eye, consisting mainly of vessels and pigment. 361.

CHOROID PLEXUS. A network of vessels in the lateral cerebral ventricle.

CHRONIC (*χρονος*, time). Long continued—in diseases, contrary of acute.

CHYLE (*χυλος*, juice). The fluid part of the food separated from the chyme by the action of the bile, to be absorbed by the lacteals. 100.

CHYLIFICATION. The process of making chyle. 84.

CHYME (*χυμος*, juice). The pulpy mass, formed by digestion of the food in the stomach. 84.

Cicatrisation. 438.

Cilia. Small, hair-like, movable bodies, found on some kind of epithelium. 65.

Ciliary body, 364—ligament, 364—process, 364.

Circulation of the blood, 124—discovery of the, 125—forces of, 149.

Cirrhosis (*κιῤῥος*, tawny). A diseased state of the liver, caused by chronic inflammatory action. 426.

Clavicle (*clavis*, a key). The collar bone.

Clinical (*κλινη*, a bed). Bedside.

Coagulation (*con*, together; *ago*, I drive). The solidifying of a fluid, generally applied to the blood or other solutions of albumen or fibrin, 118—cause of, 120.

Coccyx (*κοκκυξ*, a cuckoo). The small terminal vertebræ

Cochlea (*κοχλος*, a shell-fish). Part of the internal ear coiled like a shell. 386.

Cœlelminthia (*κοιλος*, hollow; *ελμινς*, a worm). Entozoa that have an alimentary tube. 488.

Colon. The large intestine. 90.

Color of human races. Causes of variety in. 32.

Colostrum. The first milk after delivery. 180.

Columnæ Carneæ. The prominent muscular bundles in the ventricles of the heart. 127.

Columella, the most anterior and inferior part of the septum nasi.

Commissure (*con*, together; *mitto*, I send). A suture or seam of union—of the brain. 283.

Complementary Colours. 378.

Condyle (*κονδυλος*, a knuckle). A rounded extremity of a bone.

Congestion. 442.

Conglobate Gfands (*globus*, a ball). The lymphatic or absorbent glands. 102.

Conglomerate Glands (*conglomero*, I heap together). Secreting glands. 71.

Coni Vasculosi. Part of the tubular structure of the testis.

Conjunctiva. The mucous membrane, lining the eyelids and front of the eyeball. 360.

Connective Tissue. The areolar tissue. 299.

Contractility (*traho*, I draw). The property of contracting or diminishing in length. 316.

Cookery. Philosophy of. 56.

Cophosis (*κωφος*, deaf). Deafness. 485.

Coracoid (*κοραξ*, a crow). A process of the scapula, which is a separate bone in birds and reptiles. 27.

Cordæ Willisii. Fibrous bands across the superior longitudinal sinus.

Cordæ Vocales. The organs of voice. 324.

Cordæ Tendineæ. The tendinous bands attached to the cardiac valves. 127.

Cornea (*cornu*, a horn). The transparent portion of the front of the eyeball. 360.

Corpora Arantii. 128,

Corpus Callosum, 284—cavernosum, 147—luteum, 408—striatum, 281.

Corpuscula tactus. 336.

Corpuscle. Lymph, 101—red blood, 107—white blood, 112.

Coryza. Inflammation of the mucous membrane of the nose; a cold in the head.

Coughing. 157.

Cranium (*κρανιον*, the skull). The head. 17.

Crassamentum (*crassus*, thick). The clot of blood. 118.

Creatin (*κρεας*, flesh). One of the constituents of the urine. 213.

Creatinin. A constituent of the urine resembling creatin. 213.

Crepitus (*crepo*, I crackle). The grating of broken bones; the air-sound distinctive of pneumonia.

Cretinism. A peculiar form of idiocy connected with goitre.

Crusta Petrosa or **Cementum.** The bony layer on the fang of a tooth. 68.

Crystalline Lens. 366.

Crystallization (*κρυσταλλος*, ice). The assuming of regular forms by unorganized substances. 113.

Cuneiform (*cuneus*, a wedge; *forma*, shape). Wedge-shaped.

Cupola. The upper part of the cochlea. 387.

Cuticle. The external layer of the skin. 332.

Cutis Anserina (*anser*, a goose). The rough state of the skin usually produced by cold. 334.

Cutis Vera. The true skin. 335.

Cyanosis (*κυανος*, blue). Blueness of the skin from admixture of the venous with arterial blood, usually by congenital malformation.

Cysticercus. 489.

Cystin. 214.

Cytoblastema (*κυτος*, a cell; *βλωστανω*, I bud). The process of cell growth. 13.

Dartos (*δερω*, I redden). The second or subcutaneous layer in the scrotum, consisting of involuntary muscular tissue.

Death molecular, 416—somatic, 416.

Decidua (*de*, down; *cado*, I fall). The membrane which lines the gravid uterus. 409.

Decussation of anterior pyramids. 270.

Deglutition (*deglutio*, I swallow). The act of swallowing. 73.

Defæcation (*de*, down; *fæt*, scum, filth). The evacuation of the fæces or excrementitious part of the food. 91.

Deltoid, resembling the Greek letter Δ.

Demours, Membrane of. The posterior elastic lamina of the cornea. 61.

Dentine (*dens*, a tooth). One of the structures of a tooth, the ivory. 68.

Dental Formula. The mode of stating the number of an animal's teeth. 66.

Dentition. The process of growth or the cutting of teeth. 66.

Dermoskeleton (*δερμος*, the skin; *σκελετον*, a skeleton).

The external covering of invertebrates. 306.

DERMA, the true skin. 335.

DEXTRINE, a product of the roasting of starch, resembling gum, and so named from showing right handed polarization.

DIABETES MELLITUS (δια, through; βαινω, I go). An immoderate flow of urine of a saccharine taste. 219.

DIABETES UREOSUS. An immoderate flow of urine, with a large amount of urea. 210.

DIAGNOSIS. The method of distinguishing diseases.

DIAPHORESIS (δια, through; φορεω, I carry). An increase of perspiration. 98.

DIAPHRAGM (φρασσω, I fence round). The respiratory muscle which separates the thorax from the abdomen. 154.

DIAPHYSIS (φύω, I grow). The shaft of a long bone. 311.

DIAPOPHYSIS (δια, apart; απο, from; φυω, I grow). The transverse process of the typical vertebræ. 25.

DIARRHŒA (δια, through; ῥεω, I flow). An excessive discharge from the bowel.

DIARTHROSIS (δια, through; αρθρον, a joint). A movable articulation. 305.

DIASTASE (διϊστημι, I separate). An azotized substance, found in seeds when germinating. which has the power of changing starch into sugar.

DIASTOLE (στελλω, I send). The dilatation of the heart after contraction. 127.

DIASTEMA (διαστημα, an interval). A gap, as in the line of the teeth. 23.

DIETETICS (διαιτα, food). The branch of science which treats of food or diet. 59.

DIGASTRIC (δις, double; γαστηρ, the belly). Having two bellies. A muscle of the neck. 346.

DIGESTION, 51—duration, 82—gastric, 78—intestinal, 84—stages of, 63.

DIOPTRIC MEDIA (δια, through; οπτομαι, I see). The transparent structures of the eye. 366.

DIPHTHERIA. 448.

DIPLOE (διπλους, double). The cancellated bony tissue between the two tables in the bones of the skull. 309.

DISCUS PROLIGERUS. The garnular mass surrounding the ovary. 405.

DISTOMA (Δις, twice; στομα, mouth). An entozoon. 488.

DIVERTICULUM. A short blind tube. 87.

DOMESTICATION. Effect of, in changing the food of animals. 52.

DORSAL LAMINÆ. The rudiments of the spine in fœtal life. 410.

DREAMS. 287.

DROPSY (υδωρ, water; οψις, appearance). A collection of serum.

DUCT THORACIC, 99—lymphatic right, 100—anterior thoracic, 100.

DUCTUS ARTERIOSUS, 413—Venosus, 413.

DYSENTERY (δυς, with difficulty; εντερον, bowel).

DYSURIA. Difficult micturition.

EAR, External, 380—internal, 385—middle, 381—blood in, 422.

ECCHYMOSIS (Εκχυμοω, I pour out). Extravasation of blood.

ECDYSIS (ἐκ, off; δυω, I put). A moulting or casting off.

ECTOPIA (ἐκ, out of; *τοπος*, a place). A displacement. 96.

ECTOPIA VESICÆ. A deformity where the anterior wall of the abdomen is deficient below, and the mucous membrane of bladder everted, so that the ureters open externally. 96.

EFFERENT (ex, out; *fero*, I carry). A term applied to motor nerves, 252—or to the veins of a Malpighian tuft. 127.

EIGHTH PAIR of nerves. 394.

ELASTICITY (ἐλαυνω, I drive). The property by which a body, having its form changed, returns to its original shape when released from the force applied to it. 15.

ELASTICIN. A proximate animal principle. 45.

ELASTIC TISSUE. 298.

ELECTRIC ORGANS in animals. 256.

ELECTROLYSIS (λυω, I loosen). Decomposition by an electric current. 254.

ELEMENTS of animal bodies. 38.

ELIMINATIVES (*e*, out of; *limen*, the threshold). Medicines which stimulate glands, and thus produce increased secretions. 98.

EMBOLISM. 428.

EMBRYO (ἐμβρυον). The rudimentary form of an animal. 411.

EMESIS (ἐμεω, I vomit). The act of vomiting. 83.

EMPROSTHOTONOS (εμπροσθεν, before; τεινω, I stretch). The form of tetanus, in which the body is bent forward. 484.

ENAMEL. 68.

ENARTHROSIS (εν, in; αρθρον, a joint). A ball and socket joint. 305.

ENCEPHALON (εν, in; κηφαλη, the head). The nervous contents of the cranial cavity. 282.

ENCHONDROMA (Εν, into; χονδρος, cartilage). Cartilaginous tumour. 464.

ENDOCARDIUM (ἐνδον, within; καρδια, the heart). The membrane lining the interior of the heart. 126.

ENDOLYMPH (*lympha*, water). The fluid within the membranous labyrinth. 386.

ENDOSMOSE (ἐνδον, within; ὠθεω, I push). The process by which a fluid, separated from another by a membrane, mixes with it, in a direction from without inwards. 95.

ENTOZOA (εντος, within; ξωον, an animal). Animals infesting the interior of another. 488.

ENTROPIUM (τρεπω, I turn). A turning of the eyelid, usually the upper.

EPICANTHUS (επι, on; κανθος, the corner of the eye). A semilunar fold of skin between the eye and nose. 34.

EPIDEMIC (Επι, upon; δημος a people). Applied to that class of zymotic diseases, which attack many persons at once and in the same place. 432.

EPIDERMIS or Cuticle. 332.

Epididymis (επι, on; διδυμος, the testis). The commencement of the vas deferens, forming a convoluted tube on the back of the testis.

Epiglottis (γλυττα, the tongue). The cartilage guarding the opening of the glottis. 324.

Epilepsy (επι, on; ληψις, a seizure). Loss of sensation and voluntary motion, with clonic spasms recurring at irregular intervals. 484.

Epencephalon, one of the cranial vertebræ. 25.

Epiphysis (επι, upon; φυω, I grow). The extremities of a long bone. 311.

Epithelium (επι, upon; τιθημι, I place). The fine superficial cellular layer of membranes. 64.

Epulis (επι, upon; ουλα, the gum). Fibroid tumour of the gums. 470.

Eremacausis (ηρεμα, slowly; καιω, I burn). Slow combustion; or combination of decomposing bodies with oxygen.

Erectile Tissue. 147.

Erectores Pilorum. 332.

Erysipelas (ἐρυω, I draw; πελας, near). A spreading inflammation of the skin.

Essential Elements. 38.

Ethmoid (ἡθνος, a sieve). One of the bones of the skull. 27.

Ethiopian Race. 34.

Ethnology (ἐθνος, a nation; λογος discourse). The science which treats of the varieties of man. 28.

Ethnological Dynamics. 28.

Etiology (αιτια, cause; λογος, discourse). The doctrine of the causes of diseases.

Eustachian Tube. The canal connecting the cavity of the tympanum to the mouth, discovered by *Eustachius*. 383.

Eustachian Valve. A fold of membrane at the mouth of the inferior cava, in the right auricle. 129.

Exanthemata. The eruptive fevers.

Excito-Motor action. Motion produced by an impression on the extremity of a sentient nerve, conveyed to the spinal cord, and from thence to the muscles along the motor nerve, without the intervention of sensation. 267.

Excito - Secretory action, 179.

Excrement (εκ, from; *cerno*, I separate). Fæcal matter, the undigested parts of the food which are expelled. 92.

Exosmose (*ex*, from; ὠθεω, I drive). The passage of one fluid to another, through a membrane, from within outwards. 95.

Exostosis (εξ, without; οστεον, a bone). A bony growth. 465.

Expiration (*spiro*, I breathe). 156.

Facial Nerve. 393.

Facial Angle. Of man, 17—of gorilla, 18.

Fæces (*fæx*, dregs). Excrementitious matter. 92.

Fallopian Tubes. Tubes lying in the folds of the broad ligaments of the uterus, for the transmission of the ovum from the ovary to the uterus. 406.

Falsetto. 327.

Fascia (*fascis*, a bundle). A tendinous expansion over the muscles of a limb. 317.

Fats, 43—as food, 53.

Fellinic Acid (*fel*, bile). One of the acids of the bile. 188.

Femur. The thigh bone. 311.

Fenestra Ovalis. An oval opening between the tympanum and vestibule. 382.

Fenestra Rotunda. An opening between the tympanum and cochlea. 382.

Fermentation (*ferveo*, I boil). A peculiar chemical action in organic bodies, in which their elements become re-arranged by the agency of a catalytic called a ferment.

Fibre. Muscular, 313—nerve, 249.

Fibrilla. Muscular. 313.

Fibrillation. The solidification of fibrin. 113.

Fibrin. A proximate animal principle; one of the albuminoid series. 47.

Fibro-cartilage. An animal tissue, composed of fibrous tissue and cartilage. 301.

Fibrous Tissue. White. 298.

Fibroserous Membrane. 304.

Fifth Pair of Nerves. 345.

Filiform (*filum*, a thread). Papillæ of tongue. 342.

Filum Terminale. The thread of pia mater at the termination of the spinal marrow. 259.

Fimbriæ of Fallopian Tube. The fringed border which grasps the ovary. 406.

Flocculus (*floccus*, wool). One of the lobes of the cerebellum.

Fluoride of calcium. 40.

Fœtus. The embryo or unborn animal. 411.

Follicle (*follis*, a sac). A small sac; gastric—described by *Lieburkuhn*. 77.

Fontanelle (*fons*, a fountain). An opening or space between the bones of the skull of an infant.

Food. Classification of, 52—quantity, 51—plastic, 54—respiratory, 52.

Forces of Circulation, 149—nervous, 252—of ventricles, 134—vital, 12.

Foramen Centrale of *Söemmering*. An appearance on the retina of man and the quadrumana. 370.

Fornix. An arch across the centre of the brain. 284.

Fourth Ventricle. 284.

Fourchette Bone. The conjoined clavicle of birds.

Fremissement Cataire. Purring tremor, produced by similar cause to the bellows murmur.

Function (*fungor*, I perform). The use of a part.

Funis Umbilicalis. The umbilical cord, which conveys the vessels from the mother to the fœtus. 411.

Fusiform (*fusis*, a spindle). Papillæ of tongue. 342.

Gall Bladder. 187.

Ganglion (γαγγλιον, a knot). An enlargement on a nerve, containing vesicular neurine. 250.

Ganglionic System The sympathetic nervous system. 289.

Gangrene (*γραω*, I consume). Mortification. 451.

Gases. Intestinal. 90.

Gastric Juice, 79—action of on food, 80—glands, 77—digestion, 81.

Gastro-Pulmonary Mucous Tract. 64.

Gelatin (*gelo*, I freeze). A proximate animal principle. 48.

Gemmation (*gemma*, a bud, budding). A process of cell development. 399.

Genito-Urinary. Mucous Tract. 64.

Generation. 398.

Geniculate Bodies. Two tubercles on the optic thalamus. 280.

Genus. An assemblage of species, possessing several common characters.

Germinal Spot. The opaque spot of the ovum, afterwards developed into the embryo. 406.

Germinal Vesicle. A small cell inside the yolk of the ovum. 406.

Gestation. 414.

Ginglymus (*γιγγλυμος*, a hinge). A hinge joint. 305.

Glabella. A smooth portion of the frontal bone, between the frontal eminences. 34.

Glands. 178.

Gland Cells, 89—acini or cœca of, 77—agminated, 99—lymphatic, 102—Brunner's, 88—Peyerean, 89—Haversian, 300.

Globulin. 48.

Glosso-Pharyngeal Nerve. Part of the eighth pair of cerebral nerves. 348.

Glottis. 323.

Gluten. A vegetal albuminoid. 48.

Glycerine. The base of oils. 43.

Glycogenic Bodies. Those out of which sugars are formed. 42.

Glycose (*γλυκυς*, sweet). Grape sugar. 42.

Goitre. A tumour of the thyroid body. 243.

Gomphosis (*γομφος*, a nail). A form of joint, where one bone is pegged into another, as the teeth in the jaw. 305.

Gonorrhœa (Γονη, semen; ρεω, I flow). Usually applied to a discharge of specific pus from the urethra.

Gout (*gutta*, a drop). A blood disease. 211.

Graafian Vesicles. Small bodies in the ovaries. 405.

Grey Neurine. 248.

Gubernaculum Testis. The cord which facilitates and guides the descent of the testis, in the fœtus.

Gustatory. Relating to taste. —Nerve; the part of the fifth pair of cerebral nerves, which presides over taste. 346.

Hæmatics (ἁιμα, blood). Medicines which act on the blood. 98.

Hæmadromometer (*δρομος*, speed; *μετρον*, a measure). An instrument for measuring the rapidity of the circulation of the blood. 136.

Hæmadynamometer (*δυναμις*, force; *μετρον*, measure). An instrument for measuring the force of the blood. 135.

Hæmal Arch. That portion of the vertebra which protects the vessels. 24.

Hæmal Spine. One of the processes of the typical vertebra 25.

Hæmapophysis (απο, from; φυα, I grow). Two lateral processes forming the hæmal arch of the typical vertebra. 25.

Hæmatemesis. Vomiting of blood.

Hæmatin. The colouring matter of the blood. 49.

Hæmoptysis. Spitting of blood.

Hæmorrhage (ῥηγνυμι, I burst forth). An escape of blood from its vessels.

Hair. 334.

Hallucination (*hallucinor*, I blunder). An error of the senses, or the intellect.

Hamulus. The hook in which the spiral lamina of the internal ear terminates. 387.

Hand, human, peculiarities of, 19.

Haversian Canals. Longitudinal vessels in bone described by *Havers*. 308.

Heart, 126—muscular fibres of, 126—actions, 127—force of, 134—impulse, 133—development of, 138—sounds, 130.

Hearts, Lymph. 102.

Heat, Animal. 168.

Helicine Arteries. Tortuous vessels in erectile tissue, described by *Müller*. 404.

Helicotrema, (ἑλιξ, a spiral or snail; τοημα, a hole). The opening between the scala tympani and scala vestibuli in the cochlea. 387.

Helix. The curved border of the external ear. 380.

Helminthology (Ελμις, a worm; λογος, discourse). Description of worms, especially those that are parasitic. 487.

Hemiplegia (ἡμίσυς, half; πλησσω, I strike). Loss of power in one lateral half of the body. 484

Hemispheres, Cerebral. The seat of the intellectual powers. 282.

Hepatic (ἡπαρ, the liver). Belonging to the liver. 183.

Hepatic, Veins, 184 — Duct, 185—Cells, 186.

Hepatose. A form of sugar found in the liver. 42.

Herbivora (*hèrba*, a herb; *voro*, I devour). Vegetable feeders.—Urine of, 210—heat of, 172.

Hermaphrodite (Ἑρμης, Mercury; Αφροδιτη, Venus). An individual of doubtful gender. 399.

Hernia (Ἑρνος, a branch). The protrusion of an internal viscus.

Hiccup. 157.

Hilus (the back of a bean). Applied to that part of an organ where the vessels enter

Hippocampus (ἱππος, a horse). An eminence on the floor of the lateral cerebral ventricle. 284.

Hippuric Acid (ἱππος, a horse). An acid found in the urine of horses. 212.

Histogenetic (ἱστος, a tissue,

γενναω, I produce). Forming tissues. 52.

HISTOLOGY. The science of microscopic anatomy, the description of the intimate structures of tissues.

HOMINIDÆ (*homo*, a man). The order to which man belongs according to *Linnæus*. 17.

HOMOLOGY (ὁμος, the same; λογος, a law). Structural identity. 23.

HORNY TISSUE, structures of. 333.

HOUR GLASS. Contraction of the stomach. 76.

HUMERUS. The bone of the upper arm.

HUMOURS. The contents of the eye. 366.

HUNGER. 61.

HYALOID (ὑαλος, glass). The membrane enveloping the vitreous humour. 368.

HYBERNATION (*hyberna*, winter). The act of passing the winter in a torpid condition. 169.

HYDATID. 490.

HYDROCEPHALUS (ὑδωρ, water; κεφαλη, the head). A disease consisting of water within the arachnoid sac.

HYDROGEN (γενναω, I produce). An elementary gas. 38.

HYPERÆMIA (ὑπερ, beyond; αιμα, blood). Plethora; an excess of blood. 419.

HYPERTROPHY (τρεφω, I nourish). Excessive growth of a part. 436.

HYPERINOSIS (ἰς, fibrin). Excessive quantity of fibrin in the blood. 423.

ICTHYOSIS (Ιχθυς, a fish). A scaly skin disease.

ICTERUS (ικτερος, a yellow bird; or ικτις a weasel, the eyes of which are yellow). Jaundice. 426.

IDIOPATHIC (ιδιος, peculiar; παθος, an affection). Arising spontaneous.

IDIOSYNCRASY (ιδιος, peculiar; συν, with; κρασις, temperament.) Individual peculiarity of constitution.

ILEOCŒCAL VALVES. The folds of mucous membrane which guard the opening of the ileum into the cœcum.

ILEUM (Ειλεω, I coil). The lower part of the small intestine. 87.

ILEUS. An intestinal disease in which the cavity of the bowel is obstructed.

ILIUM. The bone forming the lateral part of the pelvis.

IMPULSE of heart. 133.

INCISORS (*in*, into; *cædo*, I cut). The name given to the four front teeth in each jaw. 66.

INCUS. The second bone of the ear, so called from its resemblance to an anvil. 384.

INDICAN. 50.

INFLAMMATION. A morbid condition characterised by redness, swelling, heat, pain, and disturbançe of function.

INFLAMMATORY BLOOD. 122.

INFUNDIBULUM. A funnel; the name given to part of the kidney. 196.

INORGANIC constituents of animal bodies. 38.

INOSITE. A peculiar sugar found in muscle, spleen, &c. 42.

Insalivation. The act of mixing with saliva. 71.

Insolation (*insolo*, I dry in the sun). Exposure to the sun.

Inspiration. 154.—Muscles of, 155.

Intellect. 282.

Inter-articular Cartilages 301.

Intermittent. Applied to diseases which disappear for a while and return, as ague.

Intercellular Passages. The minutest ramification of the bronchial tubes. 153.

Interstitial Absorption. Absorption of the particles occupying interstices. 435.

Intestines. 87.

Intestinal Gases, 90.—Juice, 90.—Follicles. 87.

Intonation. 327.

Intussusception (*intus*, within; *suspicio*, I receive). A disease in which one part of an intestine is pushed within another. Invagination.

Invertebrata. Animals without a vertebral column.

Iridectomy. The operation of cutting out part of the iris.

Iris (*ἰρις*, a rainbow). The curtain or diaphragm which surrounds the pupil. 364.

Iron. 41.

Irritability. The property of acting when excited; contractility. 316.

Ischuria (Ιοχω, I restrain; *ουρον*, urine). Suppression of urine.

Isomerism. The state of bodies which possess the same elements in the same quantities, but in distinct modes of aggregation and having distinct properties.

Ivory. 68.

Jacob's Membrane. The external layer of the retina. 369.

Jaw. Motions of. 70.

Jejunum (*jejunus*, empty.) Part of the small intestines. 87.

Jugular. Belonging to the throat.

Kelænonesian (*κελαινος*, black *νησος*, an island). A name given to a subdivision of the Malay or Oceanic variety of man.

Keratin. 49.

Kreatin. 213.

Kidney, 194—structure of, 196 —microscopic anatomy, 197.

Kiestin. 213.

Labyrinth (*λαβυρινθος*, amaze). The internal ear. 385.

Labyrinth Membranous. 386

Lachrymal Gland. The gland which secretes the tears. 354.

Lacteals (*lac*, milk). The vessels which take up the chyle. 99.

Lactic Acid. In gastric juice. 80.

Lactiferous Vessels. 180.

Lactose. Sugar of milk. 42.

Lacunæ (*lacus*, a lake). Small cavities in bones. 308.

Lagophthalmus (*Λαγος*, hare). Incapability of closing the eyelids. 358

Lamina Cornea. A small prominence on the floor of the lateral cerebral ventricle.

LAMINA SPIRALIS. The bony plate which separates the two scalæ in the cochlea. 36.

LARGE INTESTINES. 90.

LARYNX (λαρυγξ, the windpipe). The upper portion of the air passages containing the organ of voice. 323.

LATERAL TRACT. A portion of the spinal cord. 264.

LEAPING. 322.

LENS CRYSTALLINE. 366.

LENTICULAR GANGLION. The nervous mass which supplies the iris 357.

LEGUMIN. A proximate organic principle. 48.

LEPIDOSIREN. An animal intermediate between the reptiles and fishes.

LEUCOCYTHÆMIA) λευκος, which; κυτος. a cell; αἱμα, blood). A disease in which the white corpuscles are in excess. 422.

LEUCOUS. White-haired or albino. 32.

LIEBERKUHN. Gastric follicles of, 77.

LIFE. 12.

LIGAMENTS (*Ligo*, I bind). 298.

LIGHT. 373.

LIMBS. Nature of, 26.

LIME. Phosphate of, 39—carbonate of, 39.

LINGUAL, or ninth nerve. 348.

LINGUALIS MUSCLE. 342.

LIPYL (λιπος, fat). The base of glycerin. 43.

LIPOIDS (λιπα, fat; ειδος, like). Non-saponifiable fats. 44.

LIPOMA. A fatty tumour. 462.

LIQUOR AMNII. The fluid in which the fœtus floats. 411

LIQUOR COTUNNII. The perilymph, or fluid outside the membranous labyrinth. 386.

LIQUOR SCARPÆ. The endolymph or fluid within the membranous labyrinth. 386.

LIQUOR SANGUINIS. The fluid in which the corpuscles float. 118.

LITHIC ACID (λιθος, a stone). Uric acid. 210.

LITHOTOMY (τεμνω, I cut). The operation for the removal of a stone from the bladder by cutting.

LITHOTRITY. The operation of breaking a stone in the bladder.

LIVER. Minute anatomy of. 184.

LOBULES. Of cerebellum, 277 —of lung. 152.

LOCUS NIGER. The black spot in the crus cerebri. 248.

LUMBAR (*Lumbus*, the loins). Relating to the loins.

LUNGS. 152.

LUNULA (*Luna*, the moon). The white mark at the foot of the nail. 333.

LYMPH (*Lympha*, water). The transparent fluid in the absorbent vessels, 104—inflammatory, 446.

LYMPHATIC vessels, 101; glands, 102.

LYRA. A peculiar marking in brain where the fornix and corpus callosum come in contact.

MACULA CRIBROSA. The perforated plate for the transmission of portio mollis. 387.

MAGNESIA. Phosphate of. 215.

MALAYS. 36.

MALLEUS. One of the bones of the ear, named from its resemblance to a hammer. 384.

MALLEOLUS (*malleus*, a hammer). The prominence at either side of the ankle.

MALPIGHIAN TUFTS, 202—pyramids, 196.

MAMMALIA (*mamma*, a breast). The name applied to the class of animals which suckle their young.

MAMMARY. Tract of mucous membrane. 179.

MAN, 17—antiquity of, 29—characteristics of, 17—classification of, by hair, 32—classification of, by skull, 32—duration of life of, 22—fossil, 29—chemistry of, 38—erect position of, 17—number of individuals, 28—osseous peculiarities of, 18—unity of species, 30—varieties of, 33—weight, 22—zoological position, 17.

MANATUS. Cervical vertebræ of. 27.

MANGANESE. 41.

MANUBRIUM (*manus*, the hand). The upper portion of the sternum. 27.

MARGARIN. 44.

MASTICATION (μαστος, the jaws). The act of chewing. 70.

MAXILLA. The jaw bone. 27.

MEATUS (*meo*, I pass). A passage.

MEATUS AUDITORIUS EXTERNUS, 381—internus, 387.

MECONIUM (μηκωνιον, the poppy juice). The first evacuation of the infant's bowel consisting of bile.

MEDIASTINUM (*medius*, the middle). The partition formed in the chest by the meeting of the two pleuræ.

MEDICINES. Laws of action of. 96.

MEDULLA OBLONGATA, 274—spinalis, 264.

MEIBOMIAN GLANDS. Those bordering the eyelid, described by *Meibomius*. 353.

MELANIN (μελας, black). Black pigment matter. 49.

MELANOSIS. A black malignant tumour. 479.

MELANOCOMUS (*coma*, hair). black-haired. 32.

MEMBRANE. Basement, 64—mucous, 64—Jacob's, of the retina, 369—pupillary, 366—tympanic, 381—serous, 303—vitelline, the capsule of the yolk, 406.

MENSTRUATION (*mensis*, a month). 407.

MESOCEPHALE (μεσος, the middle; κεφαλε, the head). The pons varolii. 279.

MESENTERIC GLANDS. 100.

MESENCEPHALON. One of the cranial vertebræ. 25.

MESMERISM. 288.

METAMORPHOSIS (μετα, change; μορφη, form). A change in shape. 399.

METRIA (μητρα, the womb). Puerperal fever.

MEZZO SOPRANO. A variety of female voice between soprano and alto. 328.

MILK. 180.

MIND. 282.

MITRAL VALVE. That guarding the left auriculo-ventricular opening. 128.

Mixed Food, necessity for. 57.
Modiolus. The axis of the cochlea. 386.
Molar Teeth. 66.
Molecule (*moles*, a mass). An atom or small particle.
Molecular. Death, 416—base of chyle, 101.
Mollusca (*mollis*, soft). A class of invertebrate animals with soft bodies.
Monad (*μονος*, alone). The smallest animalcule visible, and consisting of a simple cell.
Mongolian Variety of Man. 34.
Monotremata (*μονος*, one; *τρημα*, a opening). The class of mammals with a cloaca or single vent. 399.
Motion. Muscular, 296—ciliary, 65.
Motor Nerves. Those that preside over motion. 271.
Mouth. 64.
Mucous Membrane. 64.
Mucin. 49.
Mucus. 49.
Muscles. Actions, 316—organic, 312—animal, 313—nervous supply, 314.
Muscular Fibres, 314. Bruit, 317—coat of intestines, 87—coat of stomach, 76—fibres of heart, 126—irritality, 316—properties, 316—sense, 340—tissue, 312—tonicity, 316.
Mydriasis (*μυδαω*, I moisten). Over dilatation of the pupil. 357.
Myelitis (*μυελος*, marrow). Inflammation of spinal cord.
Myolemma. The sheath enclosing the ultimate fibrils of muscle. 313.
Myopia (*μυω*, I shut; *ωψ*, the eye). Short-sight. 376.
Myosis. Over-contraction of the pupil. 293.
Myotomy (*μυς*, a muscle; *τεμνω*, I cut). The division of a muscle.

Nabothi Glandulæ. Glands at the cervix uteri. 406.
Nails. 331.
Narcotics (*ναρκοω*, I make torpid). Medicines producing sleep. 98.
Nasal nerve. 346.
Nates. Two tubercles on the upper surface of the mesocephale. 279.
Neanderthal Skull. 30.
Necrosis (*νεκροω*, I kill).—Death of bone. 451.
Nephria (*νεφρος*, kidney). Bright's disease. 225.
Nerve. Cerebro-spinal, 271—corpuscles, 248—fibres, 249—sympathetic, 272—motor sensitive, 272—development of, 251.
Nervous Centres, 264—force, 252; system, 247.
Neuralgia (*νευρον*, a nerve; *αλγος*, pain). Pain in a nerve. 485.
Neural Arch. Part of the typical vertebra enclosing the nervous system. 24.
Neural Spine. The spinous process of a vertebra. 25.
Neurapophysis. The lateral parts of the neural arch. 25.
Neurine. The nervous substance. 247.
Neurilemma (*λεμμα*, a sheath). Sheath of a nerve fibre. 249.
Neuro-skeleton. The bones

which protect the nervous centres. 306.

Neurotics. 98.

Nitrogen (*νιτρον*, saltpetre; *γενναω*, I produce). An elementary gas. 38.

Nitrogenous. Principles, 45—Food. 54.

Noma (*Νεμω*, I eat away). A form of gangrene.

Non-nitrogenous principles—52.

Nose. 349.

Nosology (*νοσος*, disease; *λογος*, discourse). Arrangement of diseases.

Nucleus. A spot in the interior of a cell. 14.

Nutrition. 244.

Nutrition Abnormal. 435.

Occiput (*ob*, opposite; *caput*, the head). The back of the head.

Ocular Spectra. 378.

Odoriferous Glands. Those behind the corona glandis, 337.

Odours. 351.

Œdema (*οιδεω*, I swell). Swelling produced by serous effusion.

Œsophagus (*οἰω*, I carry; *φαγω*, I eat). The tube which conveys the food to the stomach. 75.

Oleaginous Food. 53.

Olecranon (*ὠλενη*, the elbow; *κρανον*, head). A process of the ulna.

Olein. 44.

Olfactory (*olfacio*, I smell). Relating to smell. Olfactory nerve. 349.

Olivary Body. Part of the medulla oblongata. 279.

Omentum (the caul). A fold of peritoneum.

Omphalo Mesenteric Vessels. 411.

Onyx (*ονυξ*, the nail). Collection of pus in the layers of the cornea.

Ophthalmic Ganglion. The ganglion that supplies the iris. 357.

Ophthalmoscope (*οφθαλμος*, the eye; *σκοπεω*, I see). A reflecting instrument for examining the interior of the eye-ball.

Optic Nerve. 371.

Optic Thalami. Two prominent masses seen in the lateral ventricles of the brain. 280.

Orbit (*orbis*, a wheel). The bony cavity which contains the eye-ball. 353.

Organic Constituents. 42.

Orthognathous. A term applied to a skull, when the face lies vertically below the cranium. 33.

Osmazome. An organic principle found in muscle and in the brain. 284.

Osmosis (*ὠθεω*, I impel). The process by which fluids pass through membranes. 94.

Ossicula Auditus. The bones of the ear. 384.

Osteo Aneurism. 467.

Osteology (*ὀστεον*, a bone; *λογος*, a discourse). A description of bones.

Otoconia (*οὐς*, the ear; *κονια*, dust). The fine powder in the membranous labyrinth of the internal ear. 386.

Otoliths. Masses of crystallized carbonate of lime in the membranous labyrinth. 386.

Ovaries. 405.

Oviparous. Producing eggs. 399.

Ovoviviparous. Producing eggs which are hatched within the body of the female. 399.

Ovum. The sac or egg containing the embryo. 406.

Oviduct (*ovum*, an egg; *duco*, I lead). The Fallopian tube. 406.

Oxaluria. 229.

Oxygen (οξυς, sour; γενναω, I produce). An elementary gas. 38.

Ozone (οζη, a stench). An allotropic form or modification of oxygen. 171.

Pabulum. Food. 51.

Pacchionian Glands. Small vascular thickenings of the dura mater. 244.

Pacinian Corpuscles. Small laminated oval bodies attached to the nerves of the fingers and toes. 336.

Palate. 74.

Palpebra. An eyelid. 353.

Pancreas (παν, all; κρεας, flesh). 84.

Pancreatic Fluid. 86.

Pancreatin or Phymatin. 86.

Panniculus Carnosus. The muscular subcutaneous expansion of lower animals.

Papilla. A conical eminence. 335.

Papillary Muscles. The projecting bands of muscular fibres in the heart. 127.

Paracentesis (παρα, beyond; κεντεω, I pierce). The operation of tapping, to withdraw fluid.

Parallel between ear and eye. 390.

Paralysis (λυω, I loosen). Loss of motion or sensation, or both, in any part of the body. 270.

Paraplegia. Paralysis of the lower half of the body. 484.

Parapophysis. The transverse process of a typical vertebra. 25.

Parasites. 486.

Parenchyma (παρεγχεω, I pour in). The areolar tissue of organs. 299.

Parotid (παρα, beyond; *ους*, the ear). The largest salivary gland, lying behind the ramus of the lower jaw. 71.

Parthenogenesis (παρθηνον, a virgin; γενναιω, I beget). The production of successive procreating individuals from one ovum. 400.

Pathognomonic. Peculiarly symptom tic.

Pathology (παθος, an affection; λογος, a discourse). The science which treats of the nature and constitution of disease. 419.

Par Vagum (*vago*, I wander). The pneumogastric nerve. 395.

Pause of heart's action. 131.

Pavement Epithelium, 64.

Peduncle (*pes*, a foot). A stem—cerebellar. 277.

Pelvis (πελλις, a bowl). The cavity below the abdomen. The membranous cavity of the kidney. 196.

Penis. 404.

Pepsin (πεπτω, I digest). The active principle of gastric juice. 80.

Peptone. A substance formed in the stomach from the albuminoids. 80.

Pericardium. The membrane enclosing the heart. 126.

Perilymph. The fluid within the bony labyrinth of the ear. 386.

Perineum (περινεω, I flow round). The space between the anus and organs of generation. 403.

Peristaltic (περι, about; στελλο, I send). The peculiar rolling motion of the intestines. 90.

Peritoneum (τεινω, I stretch). The serous membrane lining the abdominal cavity.

Perspiration (*per*, through; *spiro*, I breathe). The exhalation of fluid from the skin. 337.

Petechia (*petechio*, a flea-bite). Red spots of effused blood in fever.

Peyer's Glands. The agminate intestinal glands. 89.

Pharynx (φαρυγξ). The dilated tube between the mouth and œsophagus. 73.

Phimosis (φιμοω, I constrict). A condition of the prepuce by which the glans cannot be uncovered.

Phlebolithes (φλεψ, a vein; λιθος, a stone). The concretions sometimes found in veins.

Phlyctena (φλυω, I bubble up). A large elevation of the cuticle filled with serum.

Phosphates of lime and magnesia. 39.

Phosphorus. 41.

Phrenology (φρην, the mind; λογος, a law). The supposed science by which the disposition and qualities of the mind are made known by the external configuration of the skull. 285.

Phthisis (φθιω, I consume). Consumption, or tubercular disease of the lung. 447.

Phyma (φυω, I grow). A swelling usually ending in gangrene.

Phymatin. 86.

Physiology (φυσις, nature; λογος, a discourse). The science which treats of the functions of the various parts of the animal economy. 11.

Pia Mater. The vascular tissue surrounding the brain and spinal cord. 259.

Pica (the magpie). A depraved appetite for clay and filth.

Picromel (πικρος bitter, *mel*, honey). A principle of the bile.

Pigments. 49.

Pigmentum Nigrum. 364.

Pineal (*pinus*, a pine). A small body in the brain lying on the corpora quadrigemina. 244.

Pituitary body (*pituita*, mucus). A small body lying on the upper surface of the body of the sphenoid bone in the sella turcica, formerly supposed to secrete the mucus of the nostrils. 244.

Placenta (πλακους, a cake). A flat vascular mass by which the connexion is maintained between the fœtus and mother. 410.

Plasma. The fluid part of the circulating blood. 118.

Plastic food. 54.

Plethora. 419.

Pleurapophysis. One of the processes of the typical vertebræ represented by the ribs. 25.

Pleura (πλευρα, the side). The serous membrane covering the lungs.

Pneumogastric Nerve (πνευηων, the lungs; γαστηρ, the stomach). A part of the eighth pair which supplies the lung and stomach. 395.

Pneumonia. Inflammation of the lungs.

Podagra (πους, the food; αγρα, an attack). Gout. 211.

Pons Varolii. Part of the encephalon which connects the other subdivisions together. 279.

Portal Vein, blood of the. 239.

Portio Dura. Facial part of the seventh nerve. 393.

Portio Mollis. The auditory part of the seventh nerve. 387.

Posterior Pyramids of the Medulla Oblongata. 276.

Potash. 41.

Presbyopia (πρεσβυς, old; ωψ, the eye). Far sight from flattening of the lens and cornea. 376.

Premaxillary bone. The small bone in the lower animals and human embryo, between the two superior maxillaries. 20

Prehension (*prehendo*, I take). 64.

Primitive Dental Groove. 69.

Principles, proximate. 45.

Prostate (*pro*, before; *sto*, I stand. 404.

Prosencephalon. One of the cranial vertebræ. 25.

Protein. 45.

Prognathous (προ, forward; γναθος, the jaw). Having a prominent jaw. 18.

Psoas (ψοα, the loin). The muscles which lie at the sides of the lumbar vertebræ.

Ptyalin (πτυαλος, saliva). 72.

Pterygoid Processes (πτερον, a wing). Prominent plates of the sphenoid bone. 27.

Pulmonary Vessels. 153.

Pulp of Tooth. 67.

Pulse. 136.

Pupil. 364.

Purkinge's Test. 377.

Pus. 449.

Pyemia (πυος, pus; ἁιμα, blood). A peculiar degeneration of the blood, taking place after injuries and local inflammations. 427.

Pylorus (πυλη, a gate; ουρος, a keeper). The opening between the stomach and duodenum. 76.

Pyramidal Skulls. 32.

Pyramids of Medulla Oblongata. 275.

Pyin. The albuminoid principle of pus. 48.

Pyrexia (πυρ, fire; εχω, I hold). Inflammatory fever. 445.

Quadrigeminal Bodies. 279.

Quadrumana (*quatuor*, four; *manus*, a hand). An order of mammals including the monkey, characterized by having four hands. 18.

Rachitis (ῥαχις, the spine). A disease in which there is a deficiency of phosphates in the bones, rickets

Ramollissement. Softening. 479.

Ranine (*rana*, a frog). Belonging to the tongue.

Raphe (ραφις, a needle). A term given to parts which look as if sewn together.

Reason. 285.

Rectum (*rectus*, straight). The last part of the large intestine. 91.

Reflex Action. The act whereby an impression being conveyed by a sensitive nerve to the nervous centre, the impulse of motion is conveyed to certain muscles by a motor nerve without the will of the individual. 267.

Reflection. The turning back of a ray of light from a polished surface. 373.

Refraction (*re*, against; *frango*, I break). The changes of direction in a ray of light while passing through media of different densities. 374.

Remittent. Applied to diseases which have periodical abatements.

Renal Arteries (ῥεν, the kidney) 197.

Repair. 437.

Reproduction. 398.

Reserved Air. Air expelled by a forced expiration. 158.

Residual Air. The air which always remains in the lung, and which cannot be expelled by any effort. 158.

Respiration (*spiro*, I breathe, 150—influence of on venous circulation, 148—frequency of, 157.

Respiratory Food. 52.

Restiform Bodies (*restis*, a rope). Posterior part of medulla oblongata. 276.

Rete Mirabile. The division of an artery into branches, which again re-unite. 142.

Rete Mucosum. The soft underlayer of the cuticle. 233.

Retina (*rete*, a net). The nervous coat of the eye. 368.

Rheumatism (ῥευμα, watery fluid). A painful constitutional disease attacking the fibrous tissues, joints, and muscles. 424.

Rhinencephalon (ῥιν, the nose; ἐγκεφαλον, the head). One of the cranial vertebræ. 25.

Rhythm (ῥυθμος, proportion). The regular succession of the actions of the heart. 133.

Rigor Mortis. The stiffening of the body after death. 319.

Rima Glottidis. The narrowest part of the larynx. 324.

Roots of nerves. 271.

Running. 322.

Ruysch, membrane of. The arterial layer of the choroid of the eye. 363.

Saccharine Food. 52.

Saccular stage of the development of the teeth. 69.

Sacculus. Part of the membranous labyrinth in the ear.

Sacrum (*sacer*, sacred). The largest piece of the vertebral column placed at the back of the pelvis.

Saliva, spittle. The fluid which mixes with food during mastication. 72.

Salivary Glands. 71.

Salivin. The principle of saliva. 72.

Salts, in the body. 39.

Sanguification. 108.

Saponify (*sapo*, soap). To convert into soap.

Saponifiable Fats. 43.

Sarcina Ventriculi. 486.

Sarcolemma (*σαρξ*, flesh); *λεμμα*, a sheath). The sheath of muscular fibre. 314.

Sarcous Element. The substance of which muscular fibre is made up. 314.

Scala Tympani. The part of the cochleathat communicates with the tympanum. 386.

Scala Vestibuli. The part of the cochleathat communicates with the vestibule. 386.

Scaphoid (*σκαφος*, a boat; *ειδος*, like). Resembling a boat.

Schindylesis (*σχινδυλησις*, a cleft). A form of joint where a ridge of one bone is received into a groove in another. 305.

Schneiderian Membrane. The mucous membrane of the nose. 349.

Scirrhus. 473.

Sclerotic (*σκληρος*, hard). The fibrous tunic of the eye. 358.

Scrofula (*scrofa*, a sow). A tubercular disease. 447.

Scrotum (*scrotum*, a leather bag). The bag which contains the testis.

Scurvy, want of salts in. 41.

Sebaceous Glands (*sebum*, tallow). 337.

Secretion (*secerno*, I separate). The separation of substances from the blood. 177.

Semen. 402.

Semicircular Canals. Parts of the internal ear. 385.

Sensation. 252.

Senses. 331.

Septum. A partition.

Serolin. A fatty matter of the blood. 45.

Serosity. The water and salts of the blood). 118.

Serous Membranes. 303.

Sesamoid Bones (*σησαμον*, a grain). Osseous nodules developed in tendons.

Seventh pair of nerves. 393.

Sex. 399.

Sight. 353.

Silica. 38.

Sinus Urogenitalis. The common tube in the fœtus into which the duct of the Wolffian body and the intestine open. 412.

Sinuses, Cranial. The cerebral veins, formed by splitting of the dura mater. 263.

Sixth Nerve. 358.

Skeleton (*σκελλω*, I dry). The dry bones of an animal, 306—homology of, 23.

Sleep. 286.

Sloth. Cervical vertebræ of. 27.

Smell. 349.

Sneezing. 157.

Soap. A combination of a fatty acid and an alkali.

Soda. Carbonate, 40—phosphate, 41.

Sodium. Chloride. 40.

Solitary Glands. 89.

Somnambulism. 287.

Soprano Voice. A variety of female voice of the highest pitch. 328.

Sounds of the heart. 130.

Spasm (σπαω, I draw). An abnormal involuntary muscular contraction. 483.

Speaking Maching. 329.

Species. A collection of individuals supposed to be descended from a common parent.

Spectra. 378.

Speech. 329.

Spermatozoa (σπερμα, seed; ζωον, on animal). Floating cells in animal semen, supposed to be distinct animals. 402.

Sphenoid (σφην, a wedge). One of the cranial bones. 27.

Spherical Aberration. 376:

Sphincter. A circular muscle constricting an orifice in the body.

Sphygmometer (σφυγμος, the pulse; μετρον, a measure). An instrument for measuring the pulse.

Spigot. A subdivision of the middle lobe of the cerebellum.

Spinal marrow, 264—nerves, 271.

Spiral Lamina. The plate separating the two scalæ in the cochlea. 386.

Spirometer (*spiro*, I breathe; μετρον, a measure). An instrument to measure the quantity of air exhaled from the lungs. 159.

Spleen. 237.

Stages of Digestion. 63.

Standing. 321.

Stapes. A stirrup. One of the bones of the ear. 384.

Stapedius. A muscle attached to the stapes. 383.

Starch. 42.

Staphyloraphe (σταφυλη, the uvula; ῥαπτω, I sew). The operation of uniting a divided palate by suture.

Stearin. A fatty principle. 44.

Stereoscope (στερεος, solid; σκοπεω, I see). An instrument by which two images of an object, taken from different standpoints, are seen as if one.

Sthenic (σθενος, strength). Attended with a morbid increase of vital action.

Stillicidium (*stillo*, I drop). A dribbling of fluid.

Stomach, 76—coats of, 76—motions, 78—glands, 77.

Striata Corpora. Eminences in the lateral cerebral ventricles. 281.

Striped Muscular Fibres. 313.

Stroma. The matrix or parenchyma.

Succus Intestinalis. The intestinal fluid. 90.

Sucrose. Cane sugar. 42.

Sudoriferous Glands (*sudor*, sweat; *fero*, I bear). Sweat glands. 337.

Sugar, 42—tests for, 42.

Sulphur. 41.

Sulphocyanide of potassium, in saliva. 72.

Suprarenal (*supra*, above; *ren*, the kidney). The term applied to a body lying above the kidney. 240.

Swallowing. 73.

Sweat. 337.

Sympathetic system of nerves. 289.

Symmetrical Skulls. 32.

Symphysis (συν, together; φυω, I grow). The union of bones by means of an intervening elastic cartilage. 305.

Synarthrosis (αρθρον, a joint). An immovable joint. 305.

Synchondrosis (χονδρος, cartilage). A joint formed by the union of two bones by cartilage. 305.

Synchronous (χρονος, time). Occurring at the same time.

Syndesmosis (δεσμος, ligament). Union of two bones by dry ligaments. 305.

Synovia. The fluid existing in joints. 304.

Synovial Membrane (*ovum*, an egg). The membrane lining joints. 304.

Syntonin. Fibrin of muscle. 47.

Syssarcosis (σαρξ, flesh). The union of two bones by muscle. 305.

Systole (συστελλω, I contract). Applied to the contraction of the heart. 127.

Tænia (ταινια, a ribbon). The tape worm. 489.

Tabes. Wasting.

Talipes. Club-foot.

Tannic Acid. An acid contained in nutgalls.

Tapetum (*tapetum*, a carpet). The colored layer of the choroid in lower animals. 364.

Tartar. The secretion which accumulates around the teeth.

Tarsal Cartilage (ταρσος, a flat surface). The cartilage of the eyelid. 353.

Taste. 342.

Taurin. One of the ingredients in bile. 188.

Teeth, 65—development of, 69.

Temperature. Animal. 168.

Tenor. The highest variety of the human male voice. 328.

Tensor Tympani. A muscle which acts on the membrana tympani. 383.

Tesselated Epithelium. Scaly or pavement epithelium. 64.

Testis (a witness; because indicative of virility). 401.

Tetanus (τεινω, I stretch). A disease characterized by tonic spasm. 484.

Thalami Optici. Two prominent eminences in the lateral ventricles of the brain. 280.

Thein. The active principle of tea. 54.

Third Nerve. 357.

Thirst. 63.

Thorax (θωραξ, the chest). That cavity of the body which contains the heart and lungs. 154.

Thoracic Duct. 99.

Thrombosis. 428.

Thrombus. A swelling proproduced by blood effused from a vein.

Thymus. A large vascular body existing in the thorax of the fœtus. 241.

Thyroid Cartilage (θυρεος, a shield). One of the cartilages of the larynx. 323.

Thyroid Body. A vascular body in the forepart of the neck. 242.

Tidal Air. The air taken in during ordinary inspirations. 158.

Timbre or distinction of tone of the voice. 327.

Tissues. 298.
Tone of the voice. 327.
Tongue. 342.
Tonicity. Muscular; the antagonistic action of muscles, or their ordinary condition, during which they counterbalance each other. 316.
Tonsil. A mucous gland at each side of the fauces. 73.
Tormina. Griping pain in the bowels.
Torula Cerevisiæ. The fungus of yeast. 220.
Touch. 331.
Toxemia. 431.
Trabeculæ (*trabes*, a beam). Projecting fibrous bands in the interior of an organ.
Trachea (τραχυς, rough). The windpipe. 151.
Tracts. Mucous, 64—nervous, 265.
Transfusion. The introduction of the blood of one person into another. 123.
Traumatic (τραυμα, a wound). Belonging to a wound.
Trichina Spiralis. 488.
Trochanter (τροχαζω, I run along). The name of the two bony prominences on the upper end of the femur.
Troglodytes. A genus of apes, to which gorilla belongs. 20.
Tubercle. 447.
Tubuli. Seminiferi, 401—uriniferi, 196.
Tubes of *Bellini*, 196—of *Ferrein*, 197.
Tunica Vaginalis Oculi. 355.
Turgescence of erectile tissues. 147.
Tympánum (τυμπανον, a drum). The middle ear. 381.
Ulcer (ἑλκος, a sore). A solution of continuity of the soft parts secreting pus. 450.
Ulceration. 450.
Umbilical Cord. 412.
Umbilicus. The navel, the cicatrix left, where the funis was attached. 412.
Unleavened Bread. 58.
Urachus. The tube which connected the bladder and allantois in fœtal life. 412.
Urates. 210.
Ureter. The duct of the kidney. 203.
Urea. A principle of the urine, 207—quantity, 208.
Uremia. 427.
Urethra. 204.
Urine, 205—composition, 206.
Urina Cibi, 205—potus, 205—sanguinis, 205.
Urophœin. The coloring matter of urine. 49.

Vagina, a sheath. The passage from the vulva to the uterus in females.
Vagus (*vago*, I wander). The pneumogastric nerve, so called from its long course. 395.
Valvulæ Conniventes. The permanent folds of mucous membrane in the intestines. 87.
Vasa Efferentia. The portal veins of the kidney flowing from the Malpighian tufts. 197.
Vasa Inferentia. The arteries running into the Malpighian tuft. 197.
Vascularity of tissues. 143.
Vas Deferens. The duct of the testis. 403.

Vegetable (*vegeo*, I grow). Characteristics of. 51.

Veins. 148.

Velocity of Blood. 136.

Vena Portæ (*porta*, a gate). 183.

Venous Blood. 118.

Ventricles Cerebral. Cavities in the brain, 284—cardiac cavities in the heart, 126.

Ventriloquism. 329.

Vermicular action. 90.

Vertebræ. The bones of the spinal column, 24—typical, 24—cranial, 25.

Vertebrata. Animals with back bones.

Verumontanum. An eminence in the prostatic portion of the urethra.

Vesicular Layer of Retina. 368.

Vestibule. 385.

Vibrissæ. Hairs within the nostril. 349.

Vidian Nerve. A branch of *Meckel's* ganglion of the 5th pair, described by *Vidius*. 394.

Villi. Projections from the surface of mucous membrane, having the appearance of the pile of velvet. 88.

Vis a tergo. Moving force applied from behind. 149.

Vis a fronte. A force acting in advance—in lymphatics. 100.

Vis insita. The power supposed to be possessed by muscle of contracting by its own inherent force. 316.

Vis nervea. The property of nerves to convey the motor stimulus to muscles. 316.

Vis medicatrix naturæ. The power by which a living body is able to recover from disease or injury. 434.

Viscera. The organs of any of the great cavities.

Vision. 378.

Vital capacity. The amount of air which the lungs are capable of holding. 159.

Vitellus, or yolk of an egg. 405.

Vitreous humour. One of the transparent media of the eyeball. 368.

Vitreous table. The internal table of the bones of the skull.

Vivisection. The art of disecting living animals.

Viviparous (*vivus*, alive; *pario*, I bring forth). Bringing forth young alive. 399.

Vocal cords. 324.

Voice. 323.

Voluntary muscles. Those that are obedient to the stimulus of the will. 313.

Vomiting. 83.

Walking. 322.

Water. 39

Weights of bones of various parts. 310.

White Corpuscles, 112—neurine. 249.

Willis, Circle of. A remarkable arterial inosculation on the base of the brain. 261.

Wounds. 438.

Xanthous (ξανθος, yellow). Yellow, applied to the variety of man with yellow or light hair, 32.

Xanthin. One of the constituents of urine. 213.

Xiphoid Cartilage (ξιφος, a sword). The cartilage at the extremity of the sternum.

Yawning. 157.

Yellow Elastic Tissue. 298.

Yolk. Part of the ovum. 405.

Zoology (ζωον, an animal; λογος, a discourse). The natural history of the animal kingdom.

Zoster (ζωστηρ. a girdle). A vesicular disease encircling the body like a girdle: the shingles.

Zygoma (ζυγοω, I yoke together). A bony arch, uniting the malar and temporal bones.

Zygapophyses. Articulating processes on the typical vertebra, four in number. 25.

Zymosis (ζυμοω, I leaven). A term applied to the mode of action of specific poisons in producing disease, by a process analogous to fermentation. 432.

THE END.